JOURNAL OF THE IRON AND STEEL INSTITUTE

JANUARY 1961

Volume 197 Part 1

Established 1869
Incorporated by Royal Charter 1899

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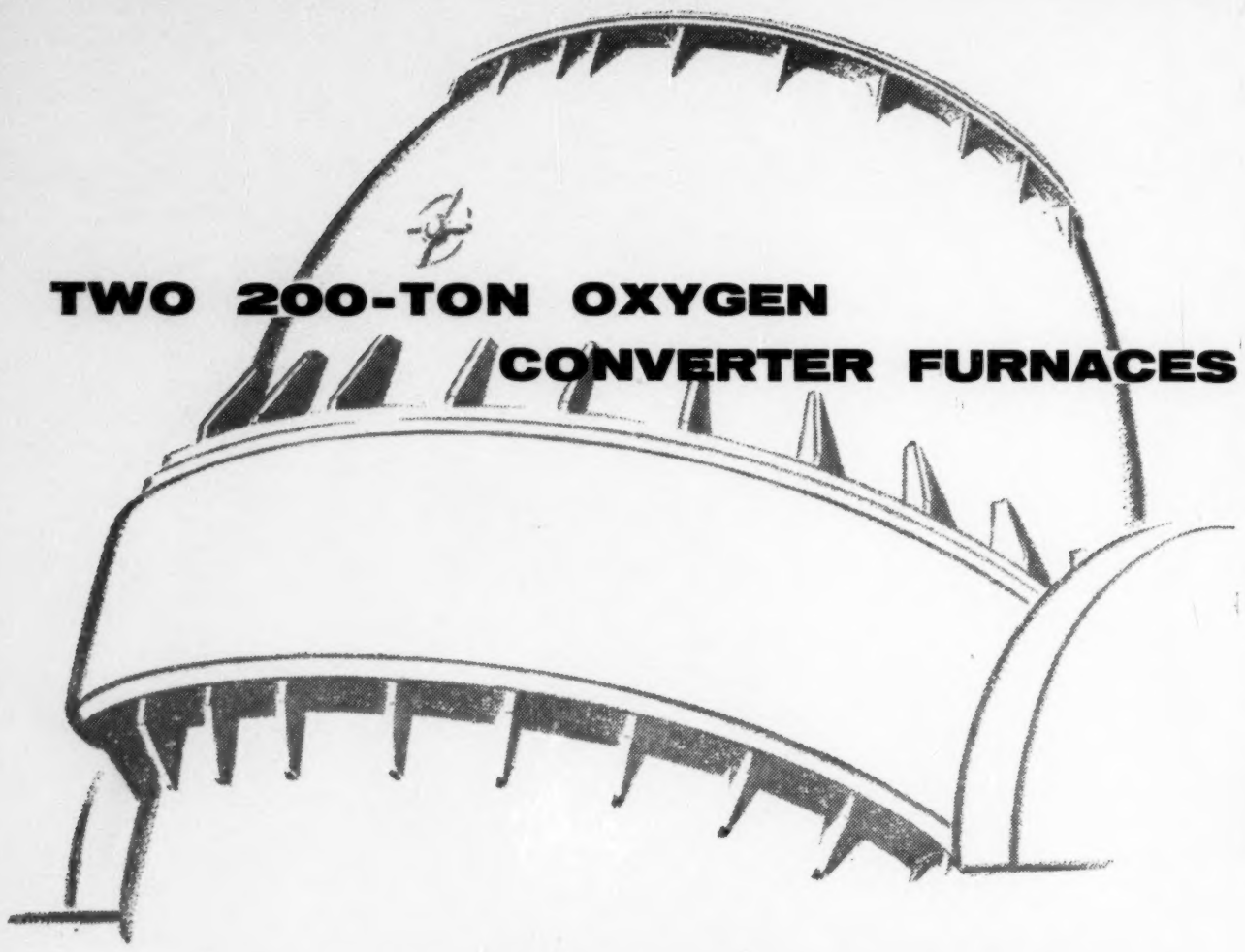

TWO 200-TON OXYGEN CONVERTER FURNACES

for Australia

Davy and United Engineering Company Limited, a member of the Davy-Ashmore Group, has secured the order to build two surface blown oxygen converter furnaces for the Newcastle Works, New South Wales, of The Broken Hill Proprietary Co. Ltd. Each of these furnaces will have a capacity at each charge of 200 tons of liquid steel.

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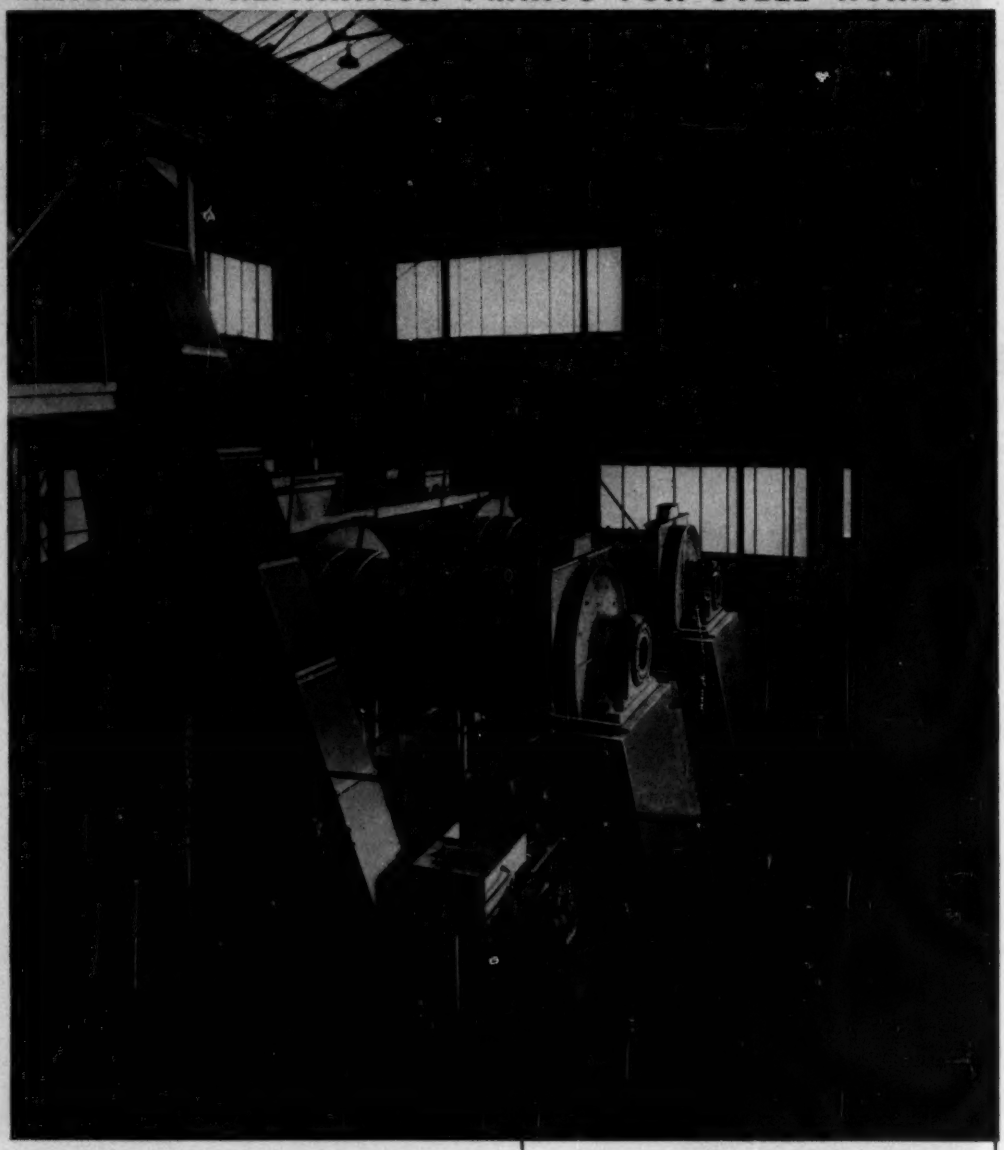

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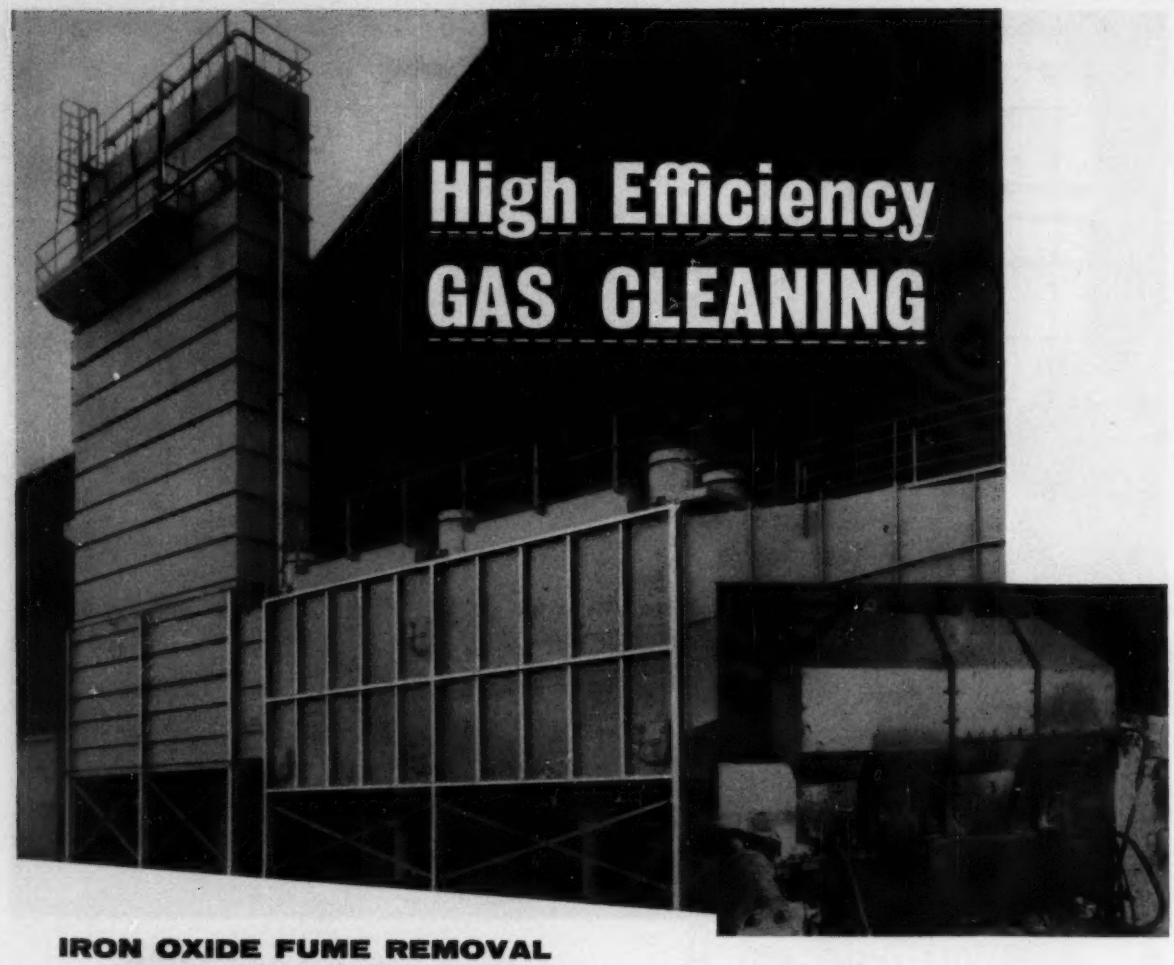
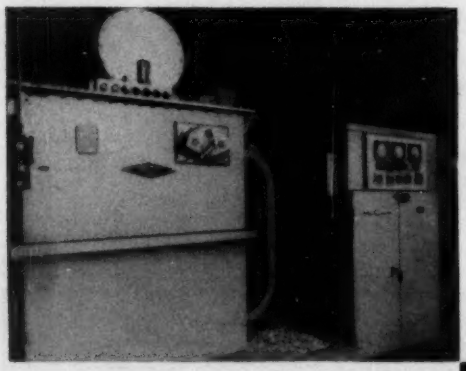


IRON OXIDE FUME REMOVAL FROM DESEAMING PLANT

An irrigated Holmes-Elex Electrical Precipitator preceded by a gas storage/wash tower cleaning exhaust air from the deseaming plant at the Rotherham Works of Messrs. Steel Peech & Tozer (Branch of the United Steel Companies Limited). The photograph inset shows the exhaust hood enclosing the deseaming plant



The first electrical precipitator to operate on deseaming plant in the U.K. was installed by our Gas Cleaning Division at the Corby Works of Messrs. Stewarts & Lloyds Ltd. in 1954. A further installation was recently commissioned at the Bilston Works of the same company.

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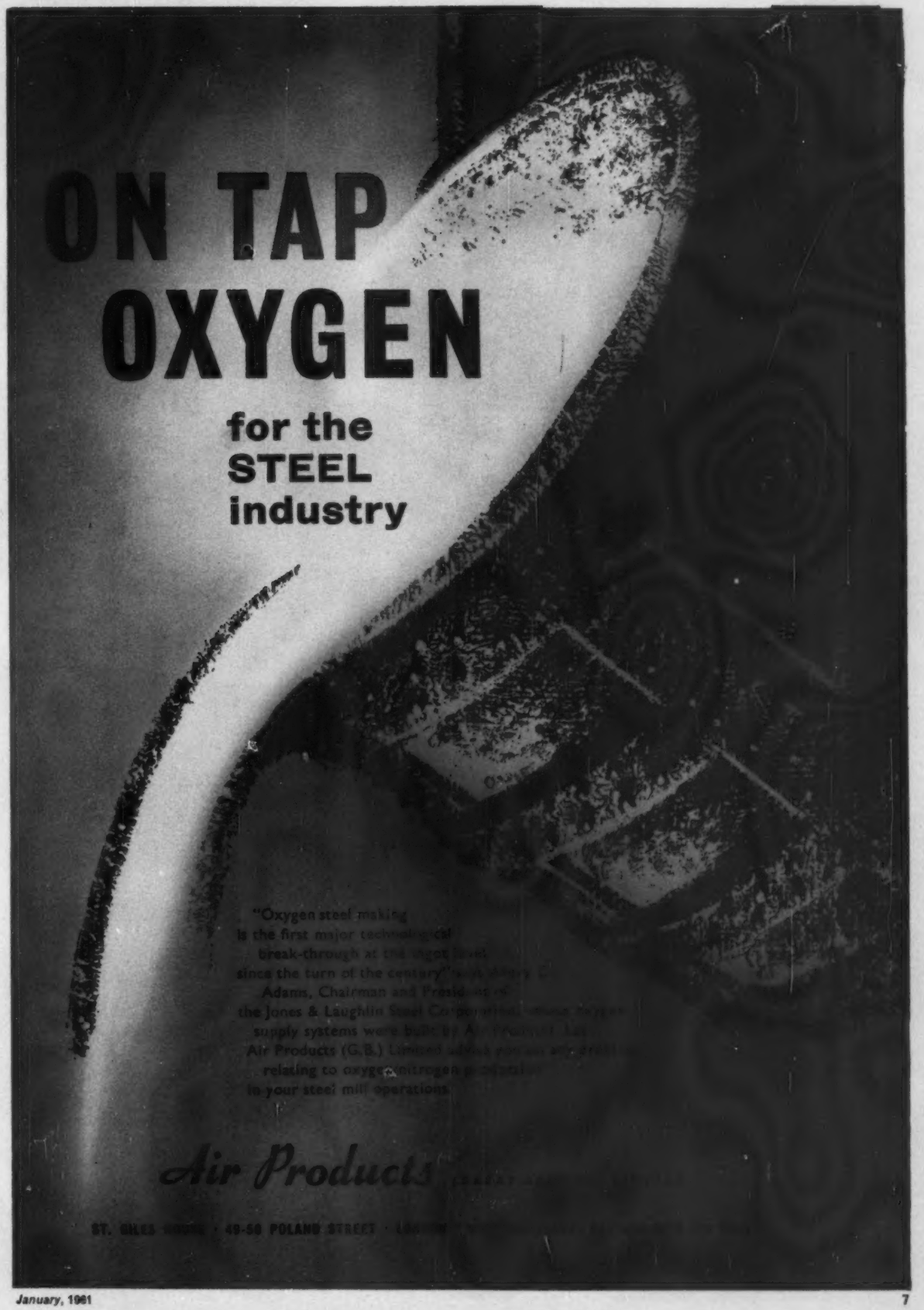
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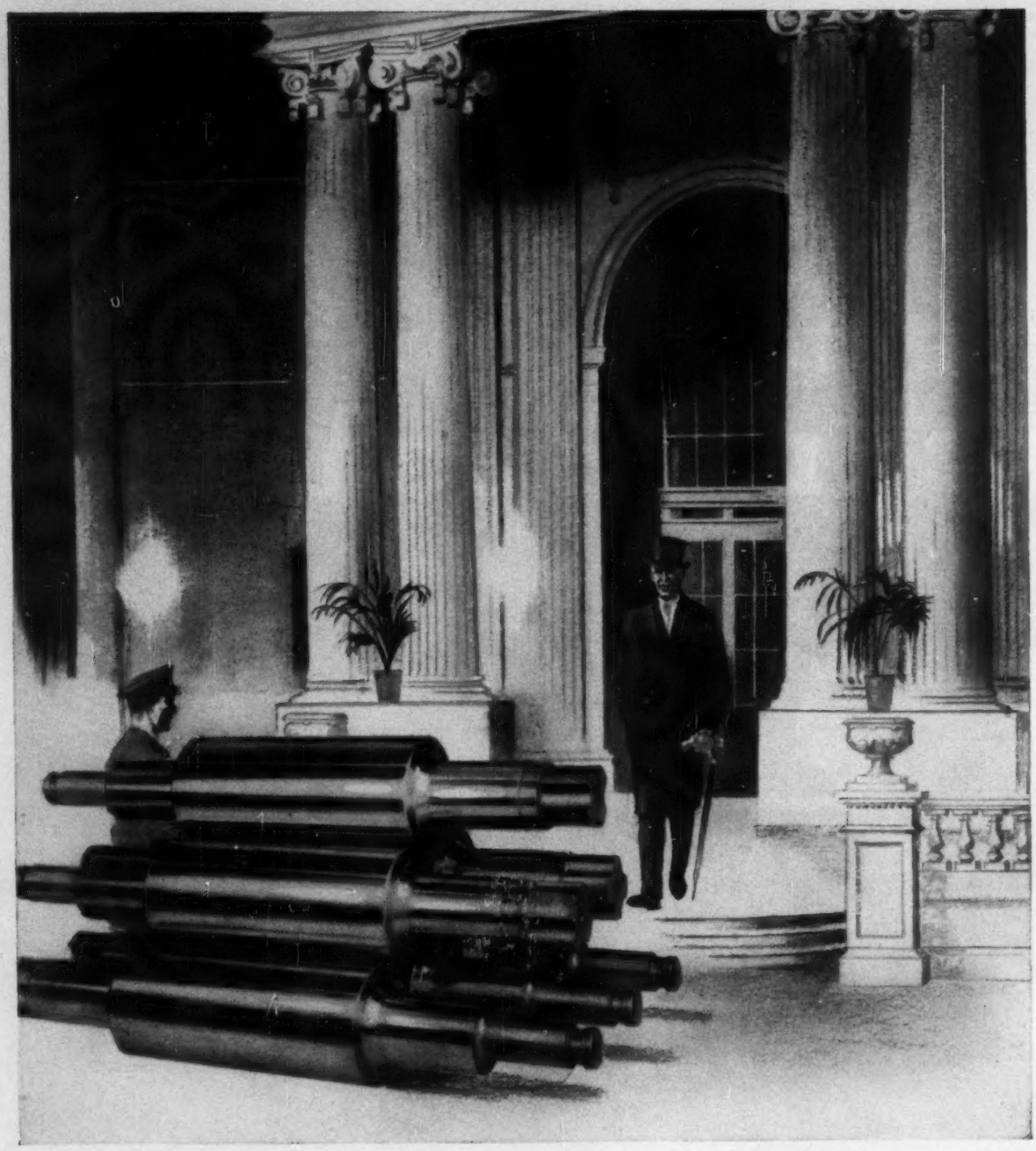

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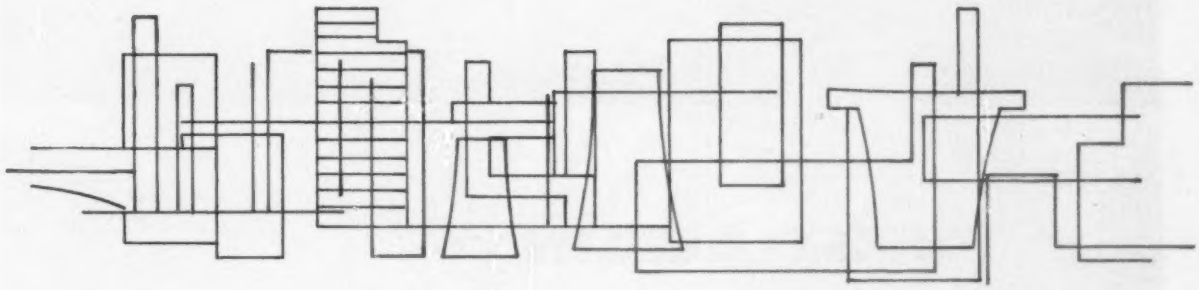

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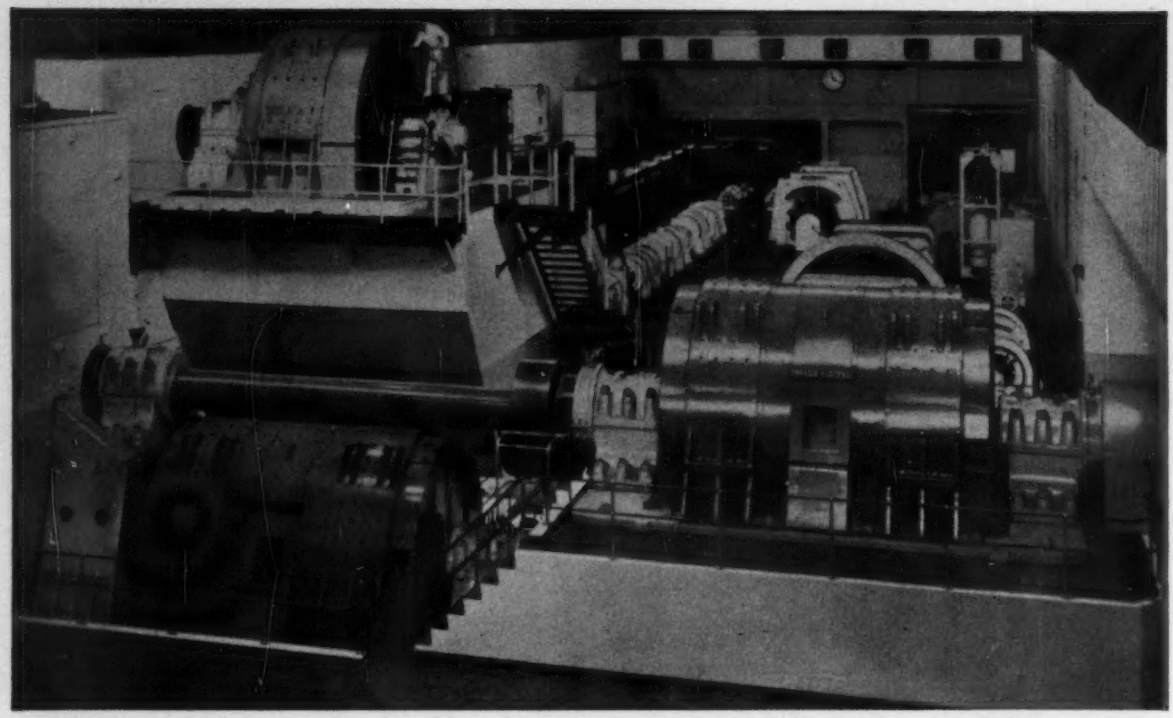

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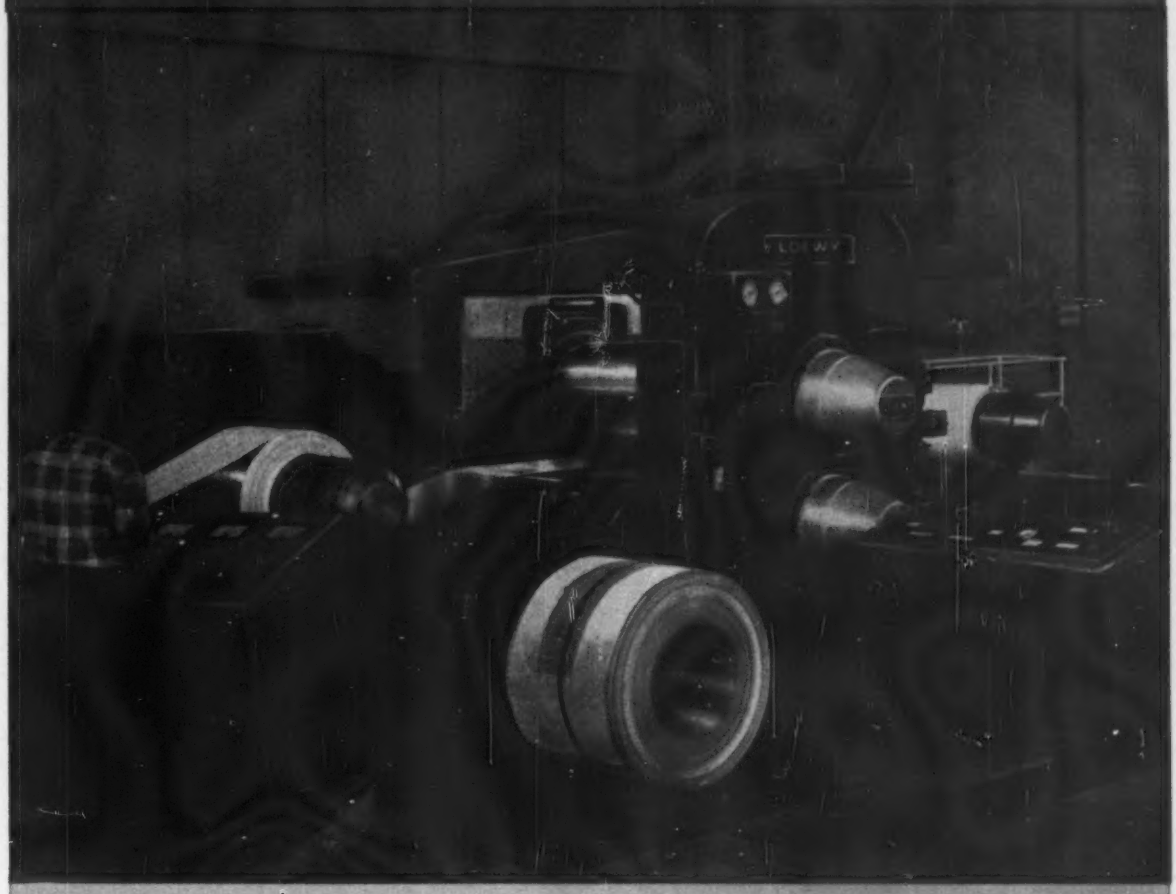

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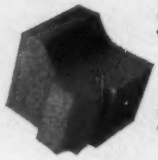

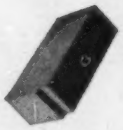

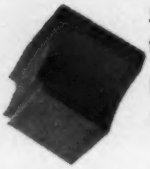

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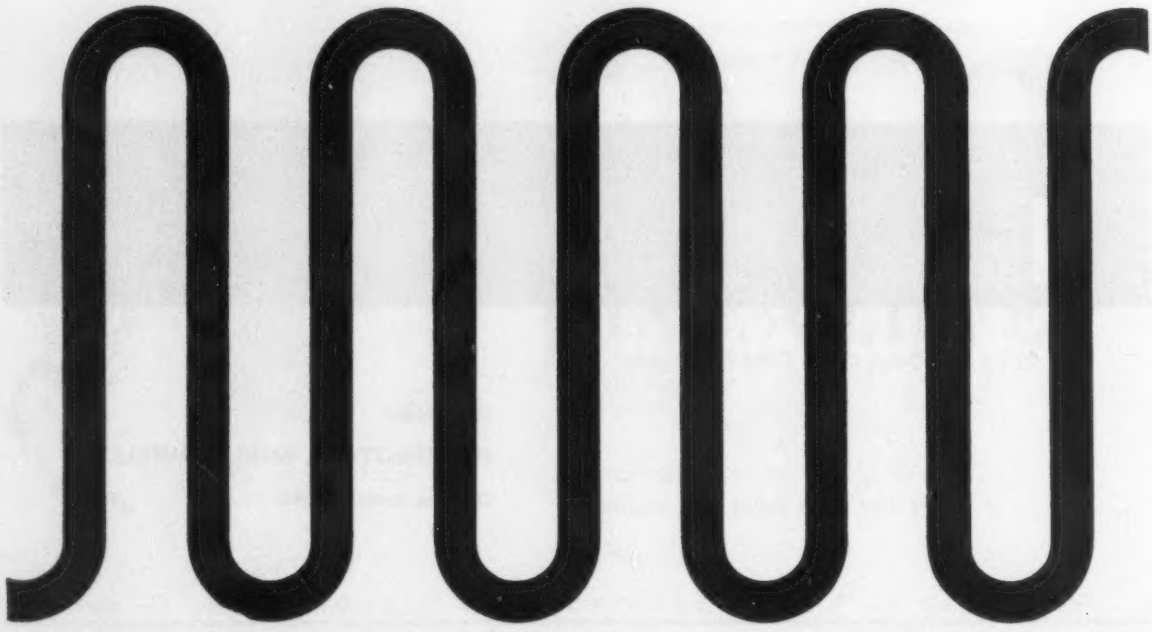

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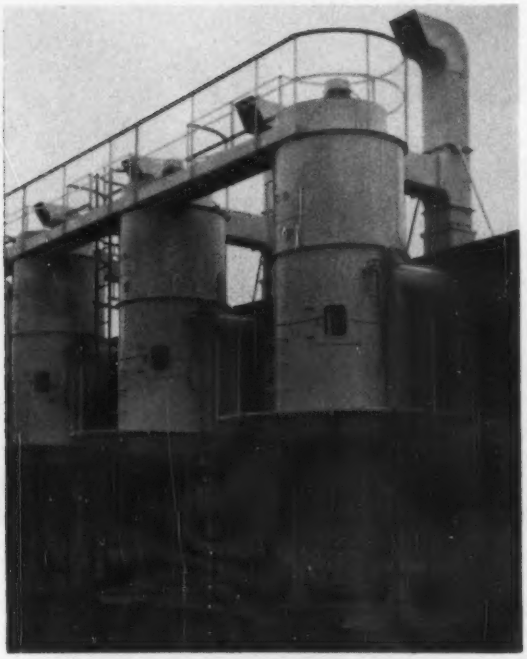

If you have a dust recovery or powder handling problem of any kind, you will find our latest brochure useful and interesting. In it we discuss dust collection in general and give numerous examples of the application of dust recovery equipment to various industries. The information in the brochure is based on many years' experience in dealing with practically every kind of material in powder or fibrous form. It also contains illustrations showing different types of equipment varying from large centralized plant to small units for use with individual grinding or polishing machines. Enquiries invited to
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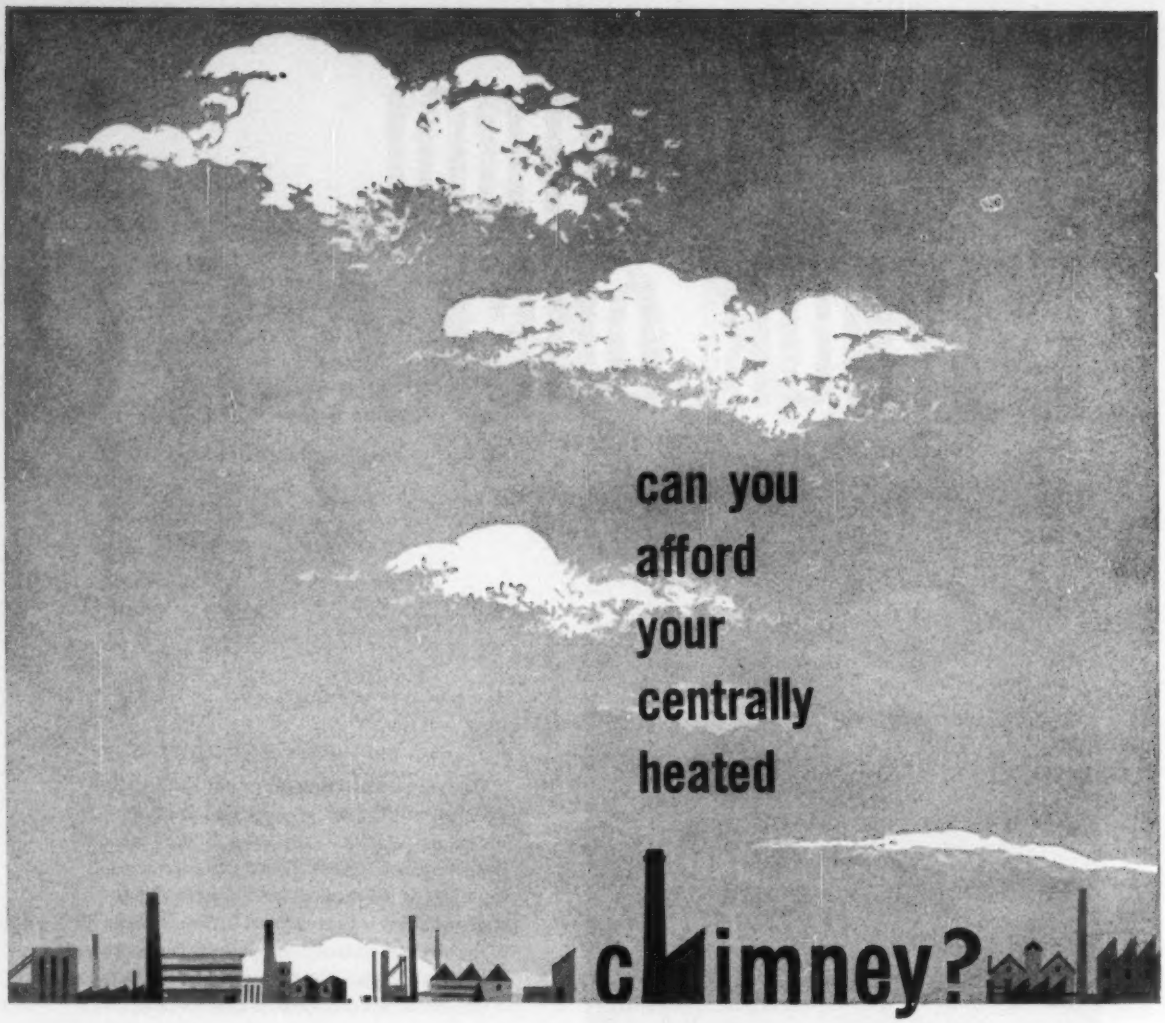

With rising production costs it's hardly likely. The people to see are Spencer-Bonecourt-Clarkson who for over forty years have been experts in waste heat recovery for steam raising in a wide range of industries. In addition to fire-tube boilers, *S-B-C now also supply water-tube boilers.*

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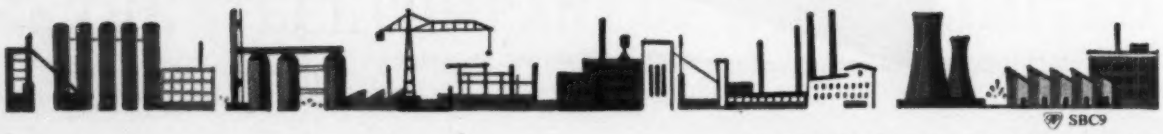

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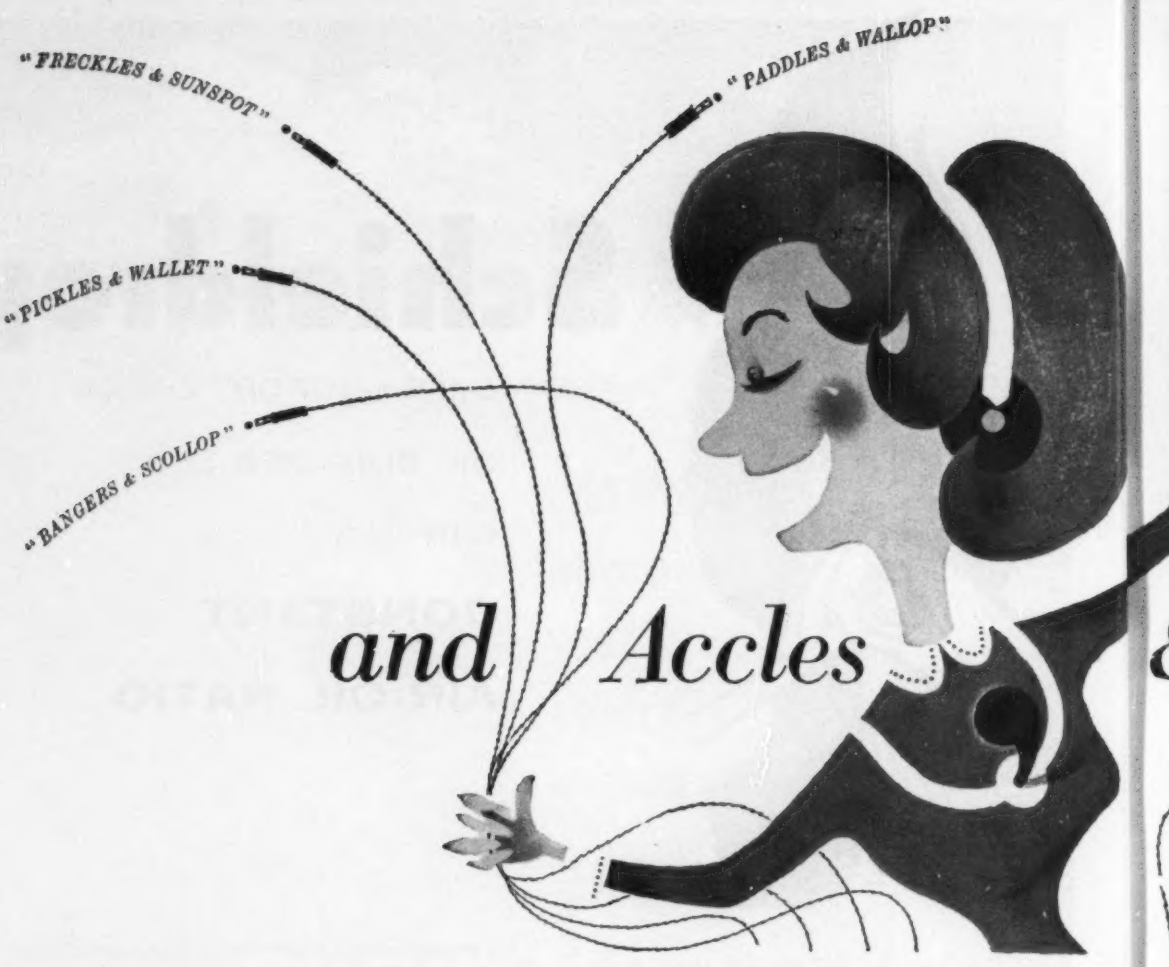


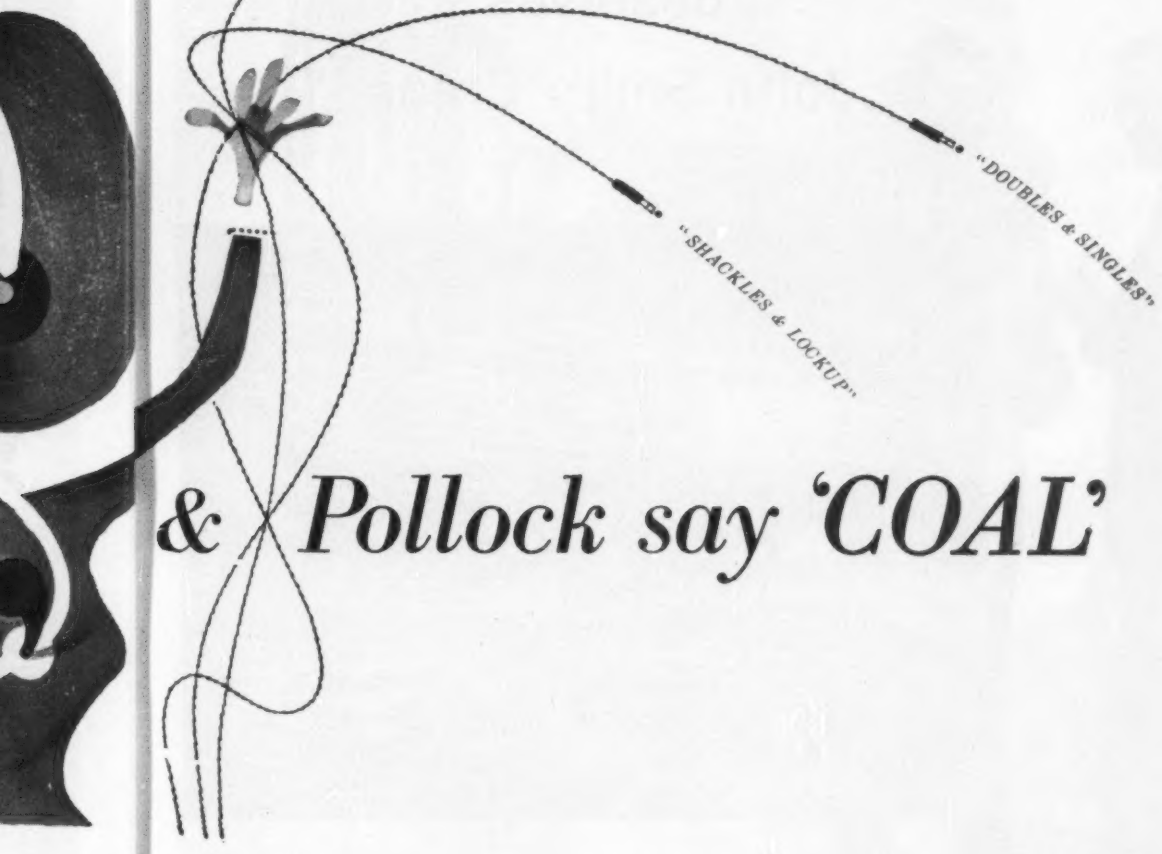
TO CHANGE a lump of stainless steel into a tiny tube ·011/·0115" o/d x ·005/·007" i/d, used for the manufacture of automatic knitting needles in the textile industry, is only one of the many miracles that Accles & Pollock create for science and industry at their works at Oldbury, Birmingham.

Behind this brilliant engineering know-how that will design and produce tubes of any size, any complexity, is the direction and impetus of a dynamic management that secures long-term advantages as well as immediate gain when making decisions. That's why Accles and Pollock choose *coal* to keep their boilerhouse at its efficiency peak. Their experience has proved that coal, mechanically stoked, *gives the maximum heat for the lowest cost:* and they know that there is no shortage of coal—the home produced fuel.

When the question of fuel for your factory is on the agenda, remember Accles & Pollock. Their choice is coal for a progressive and prosperous industry. Even if you get the name wrong, you get the decision right when you follow their example.

PROGRESSIVE INDUSTRY IS GOING FORWARD

ISSUED BY THE NATIONAL COAL BOARD



& Pollock say 'COAL'

Mr. W. E. Powell, fuel engineer, comments: "Our boilers were designed, primarily, for burning the slack grading of solid fuel. Following experiments into ultimate economies, however, it was decided to change to the better fuel of the 'bean' grading. Under test, it was found that solid fuel gave us excellent combustion conditions, at a challenging price per thousand pounds of steam. By making use of modern mechanical means of firing we are able to maintain strict control of operation practice.

The boilers are of the non-flue type, and when fitted with grit arresters they satisfy all local and national regulations governing grit and smoke densities.

Most fuels can be controlled to give economical generation on the level obtained by solid fuel, but the use of coal does not entail the provision of ancillary equipment so necessary to the use of other heating mediums.

The present boilers have been in existence some ten to twelve years, and during that period we have experimented with all available means towards obtaining the best from our equipment. All our tests bring us back to the use of the 'bean' size coal. Given this heating medium, the operators have no difficulty in maintaining the efficiency level nominated by us. That is why we shall continue to use coal at Accles and Pollock."

And here are some key facts and figures about the Accles & Pollock boilerhouse at Oldbury

Number of boilers	5 water tube
Method of firing	Chain grate stoker
Steam pressure	120 lbs. per sq. inch
Steam temperature	340°F.
Continuous max. rating	72,000 lb. per hour
Annual fuel consumption	20,000 tons of coal

ON COAL

"That new Steelworks deserves a John Smith Crane!"

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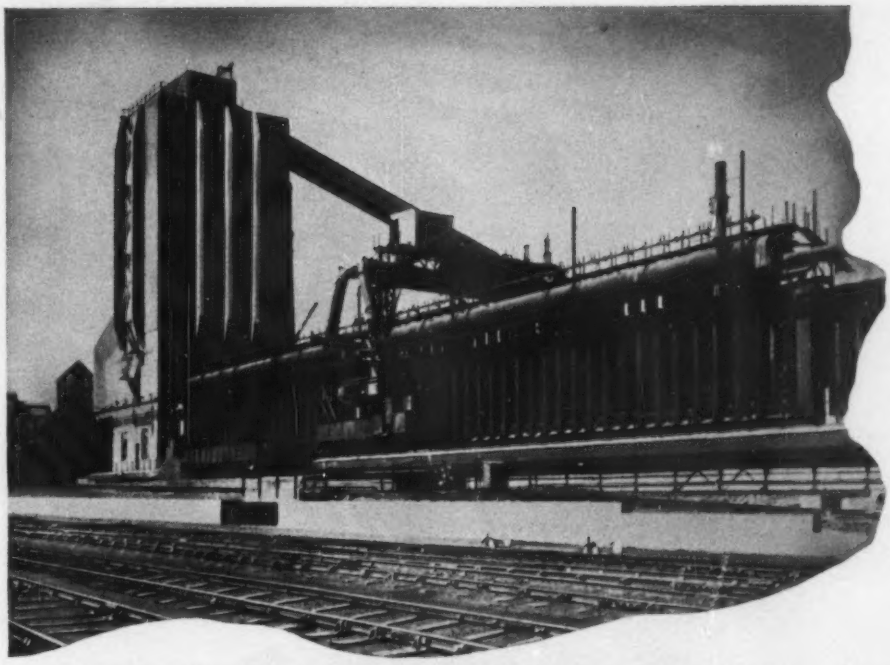

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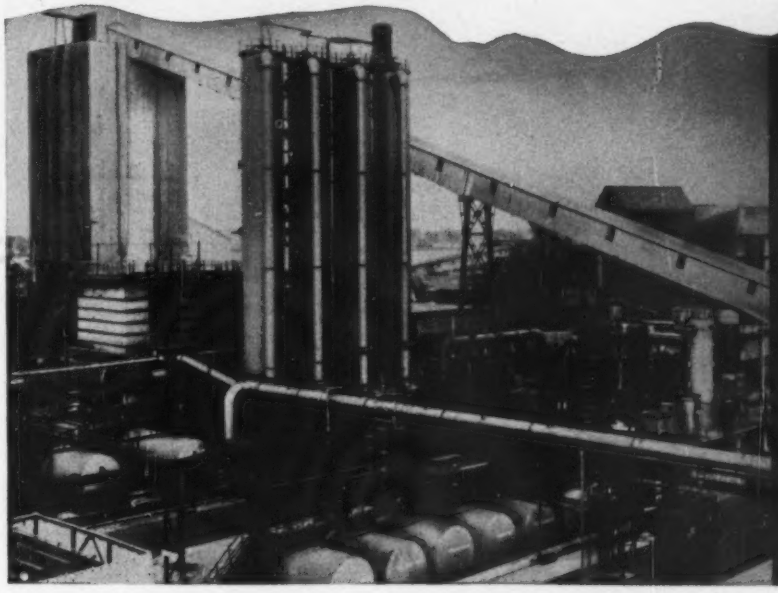

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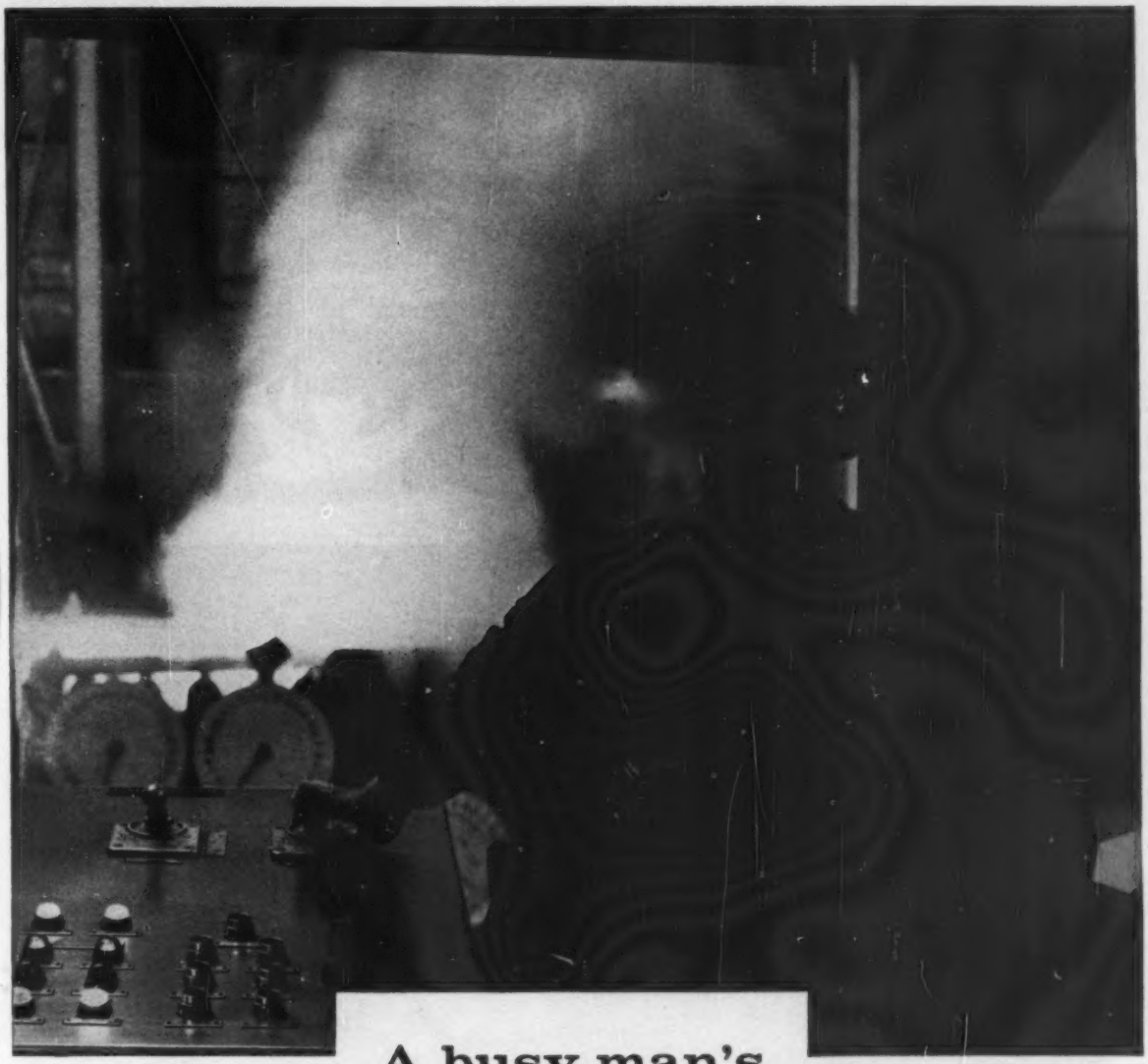

A busy man's guide to Britain's steel progress

WINSTON CHURCHILL kept his finger on the pulse of things by asking for important information "on one side of a sheet of paper".

The post-war achievements of the British steel industry would fill a book. Here, for the busy man whose eye we have this minute, is an account of what is happening now.

PRODUCTION The British steel industry produced over 24 million tons of steel in 1960 – compared with 20 million tons in 1959. Output is now about *double* the pre-war figure. Production of alloy steels – especially stainless steel – is expanding particularly rapidly.

PLANT Since the end of 1946, almost £900,000,000 has been spent on development. Continued modernisation and expansion – now costing some £125,000,000 a year – will provide steel capacity for over 30 million tons by 1965. Pig iron output per furnace and open hearth steel output per furnace are both more than double pre-war. With the need for ever-increasing efficiency and economy, ore beneficiation has made great strides and fuel consumption per ton of iron has been reduced by about 25% since the war. Use of oxygen for steelmaking is rapidly increasing.

INDUSTRIAL RELATIONS The industry keeps its remarkably good record for settling industrial disputes without recourse to strike action. British steel workers are often sons and grandsons of steel workers, richly endowed with traditional skills. Making steel exactly to specification is more than a commercial requirement; it's a matter of pride.

PRICES British steel prices have been keenly competitive since the war with those of other major European producers and well below the American price level – and the quality of British steel is unsurpassed.

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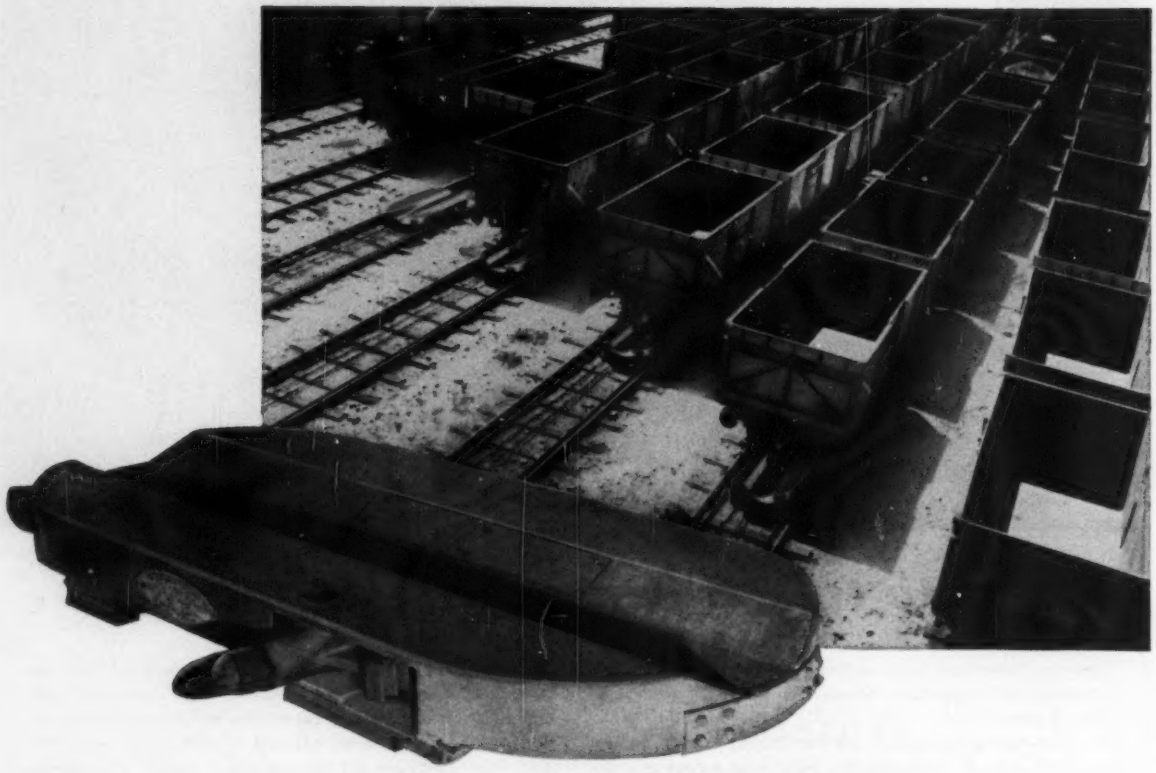

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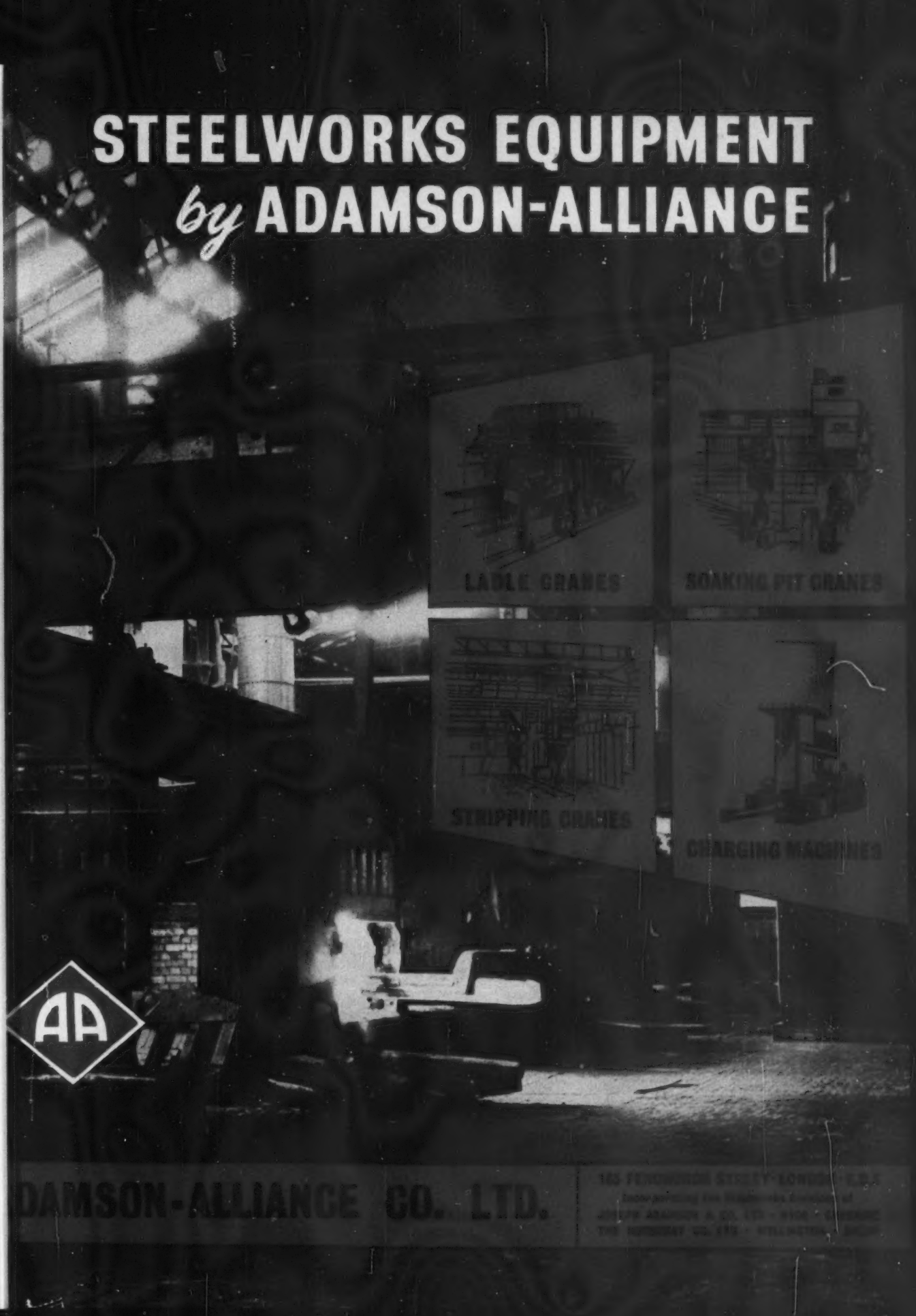

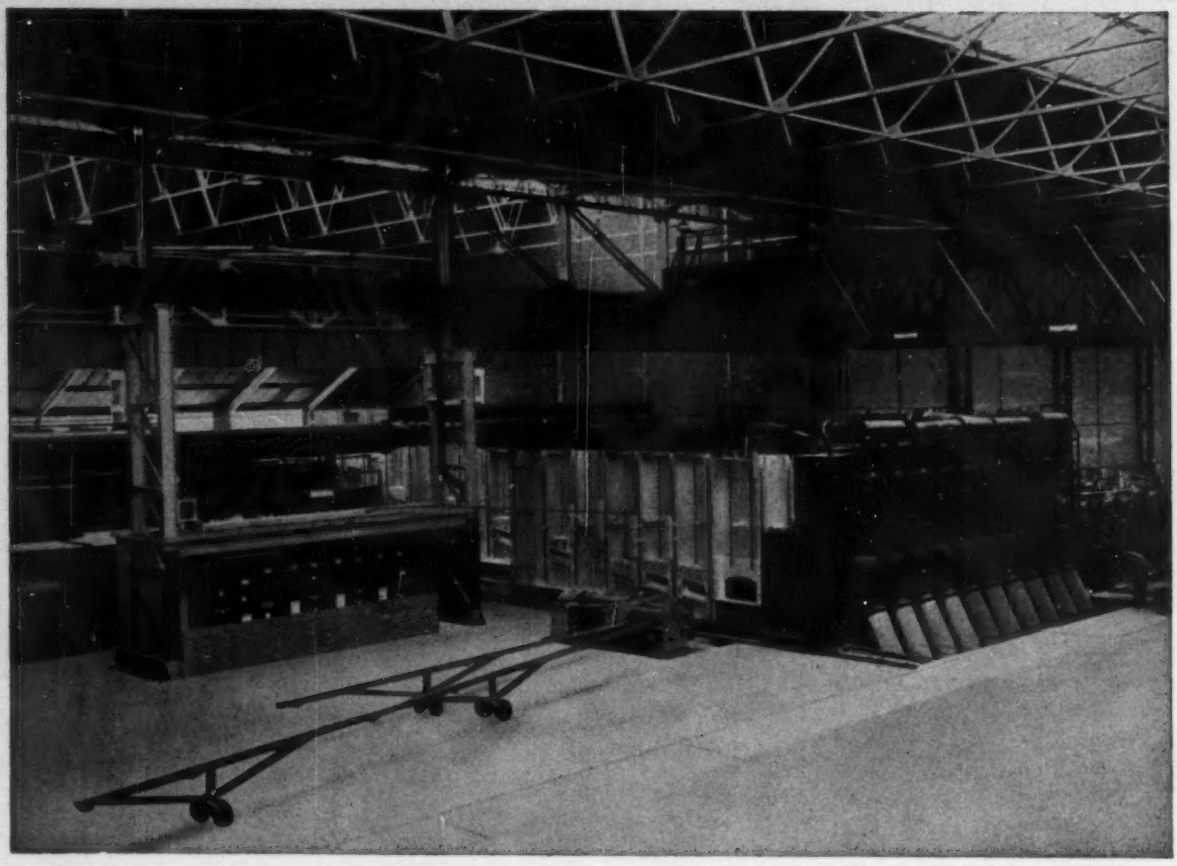

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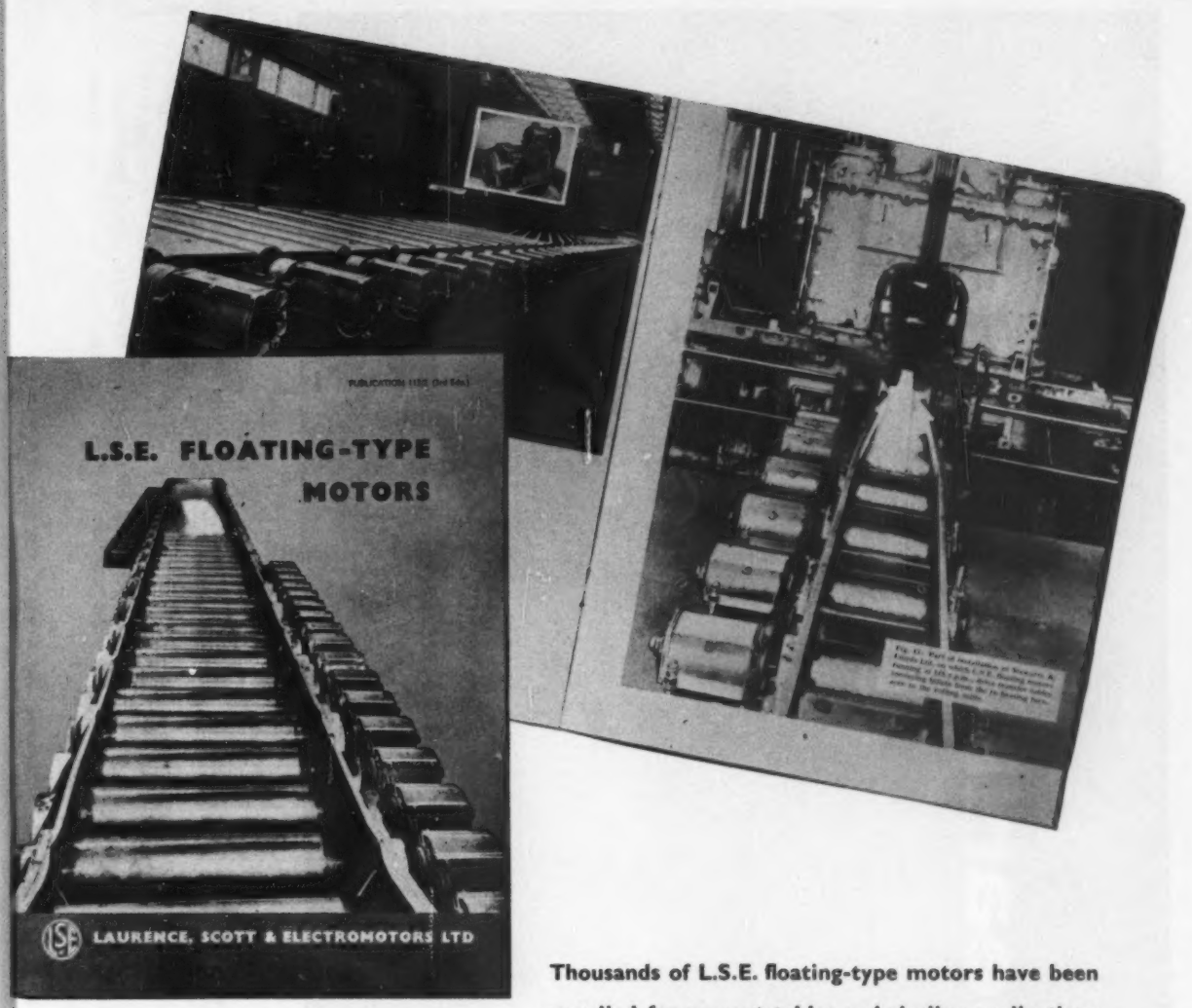

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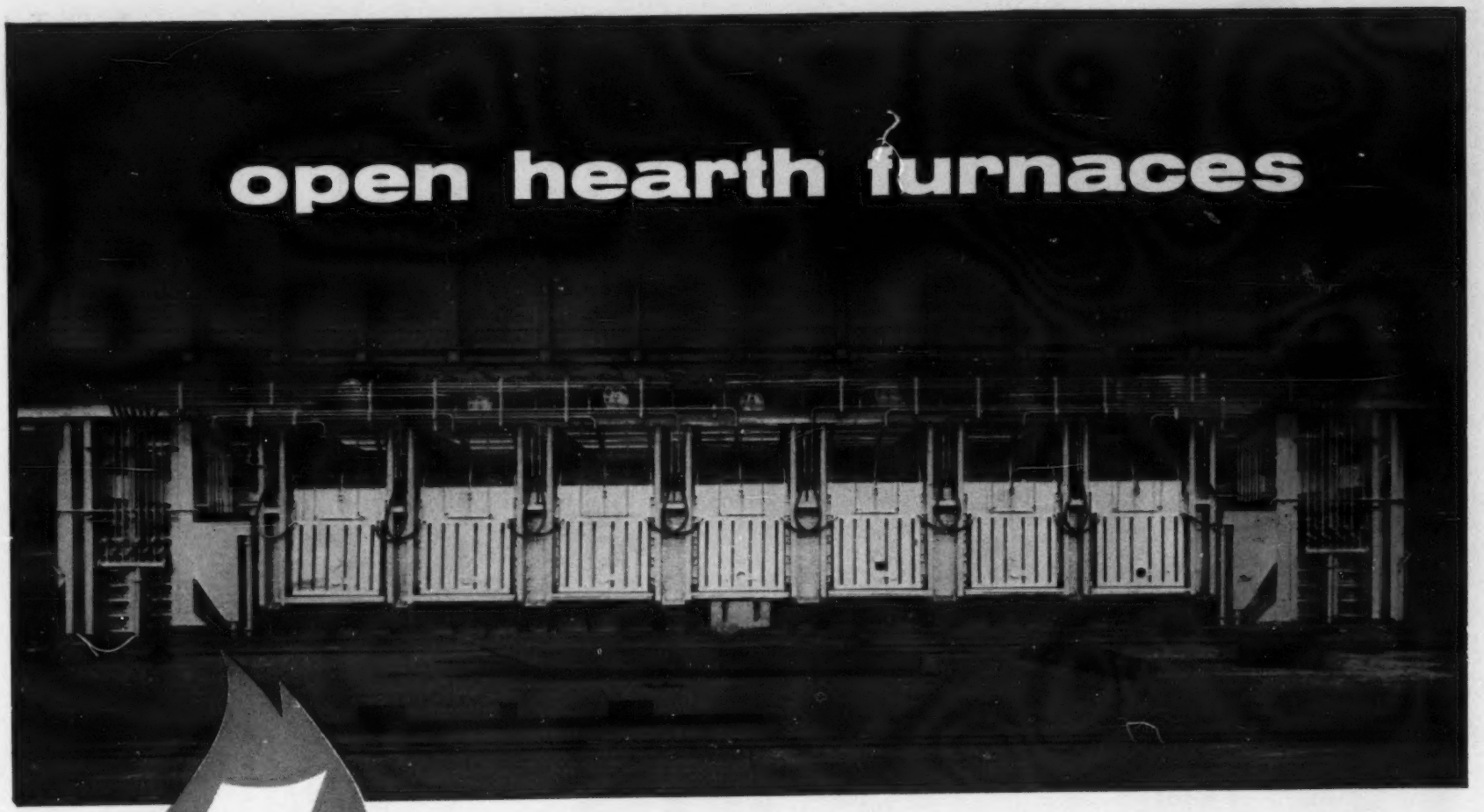

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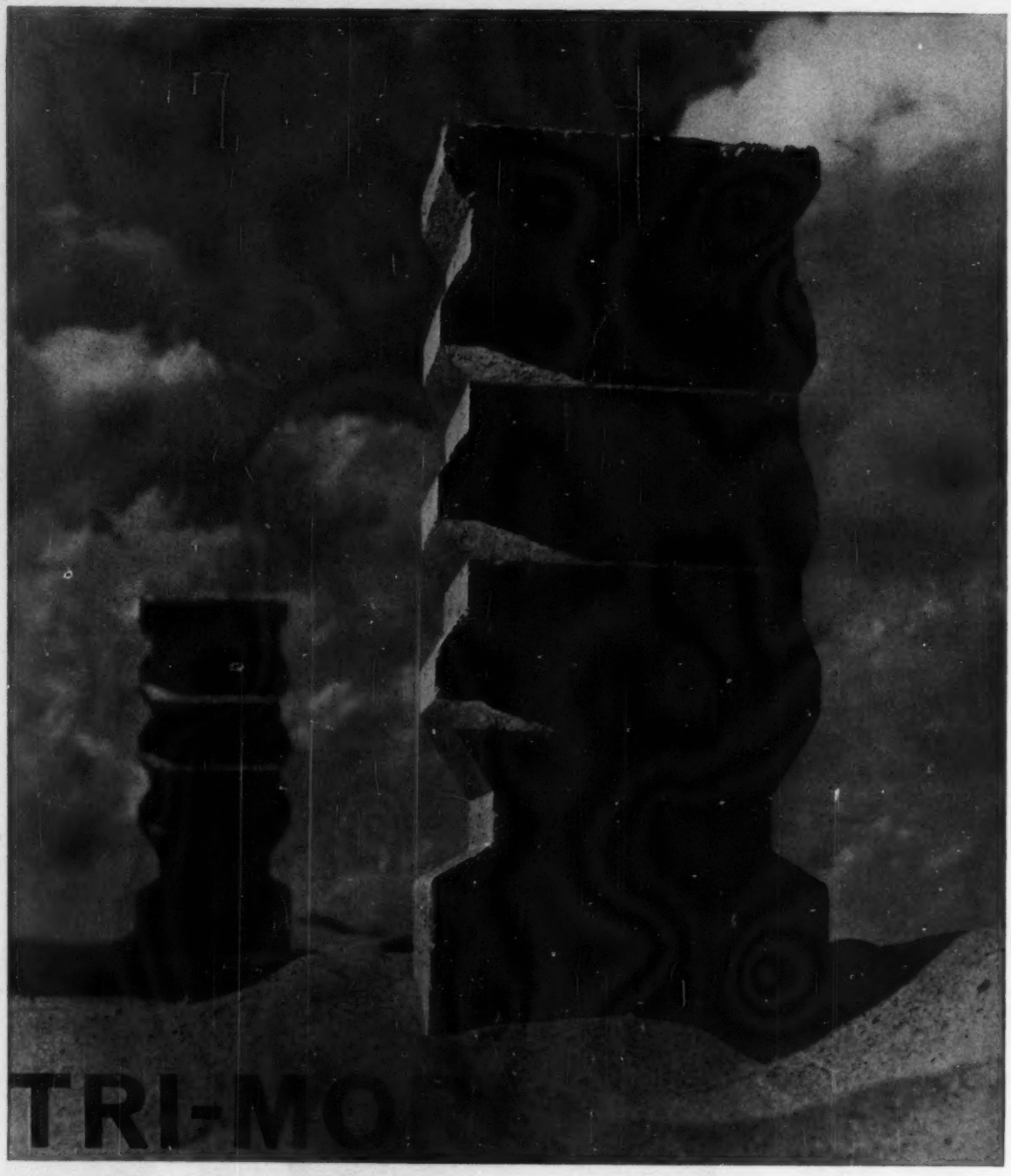

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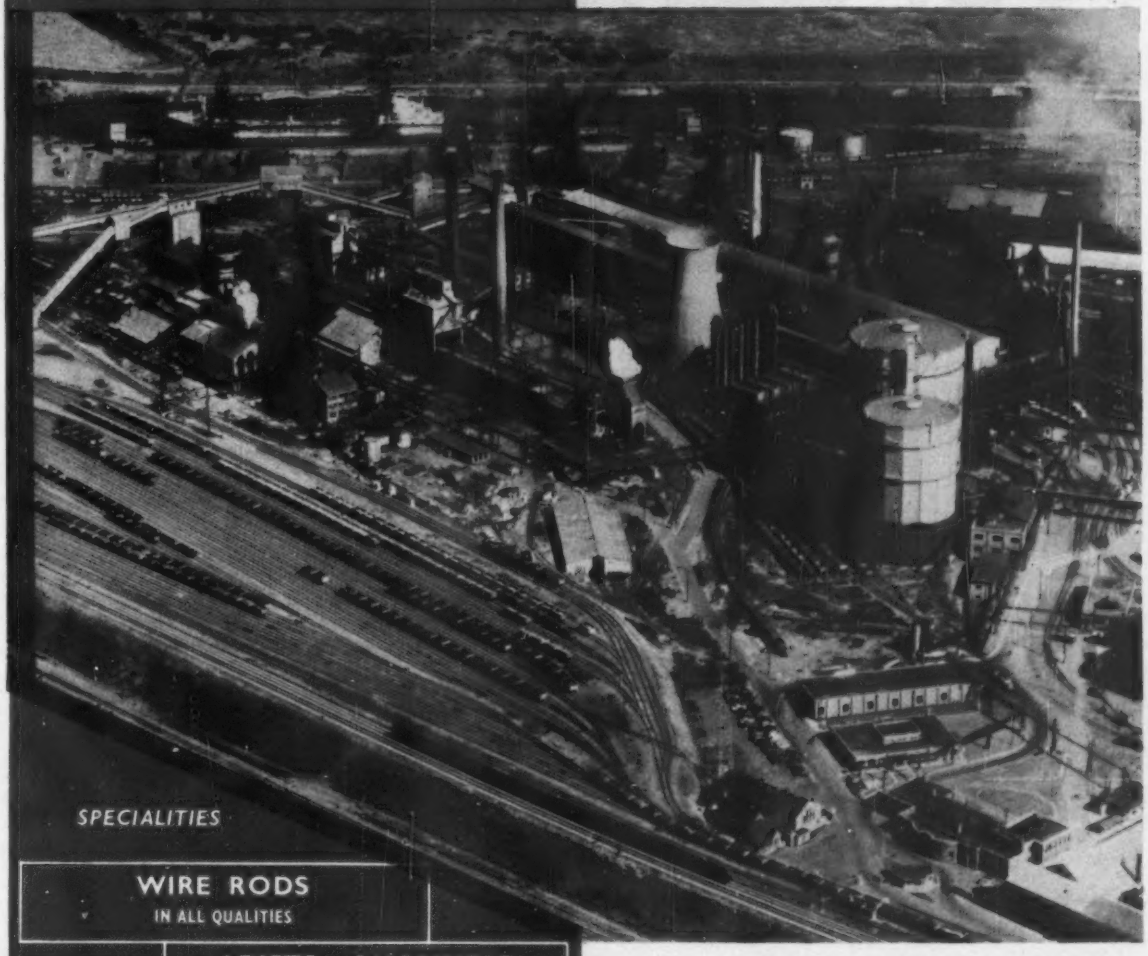

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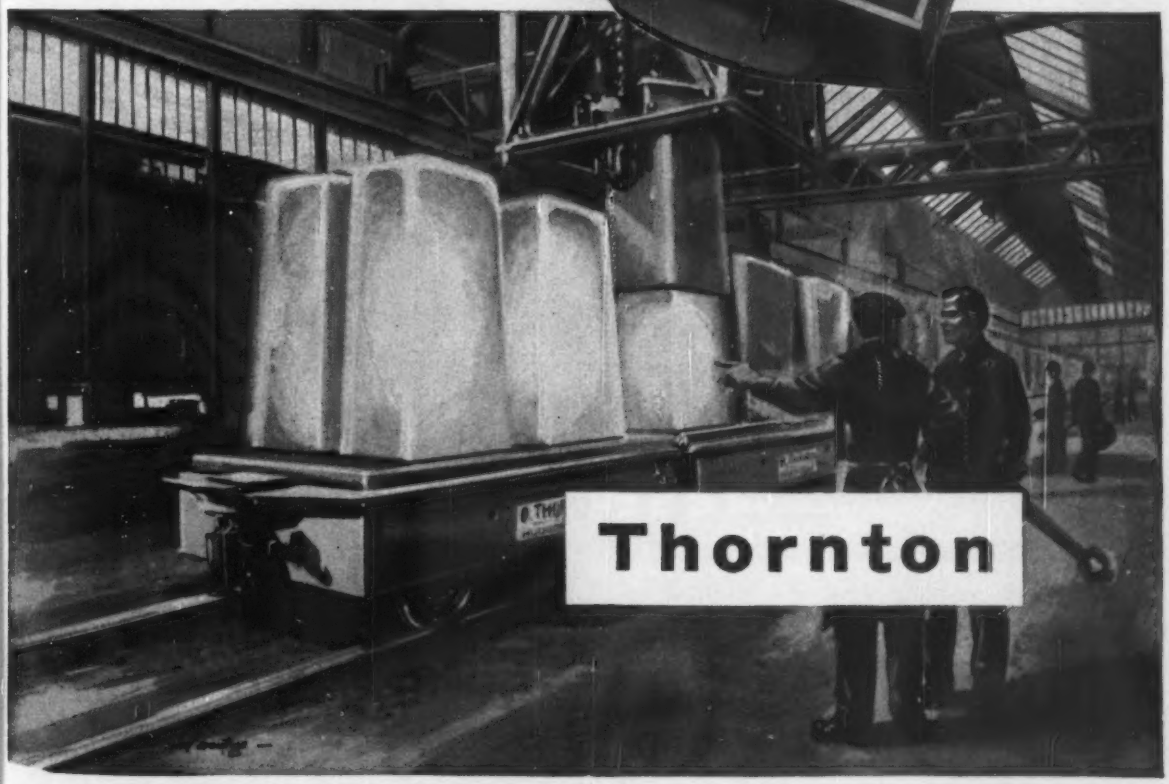

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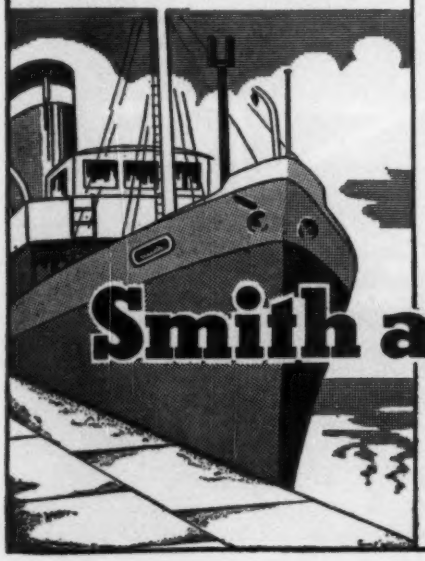

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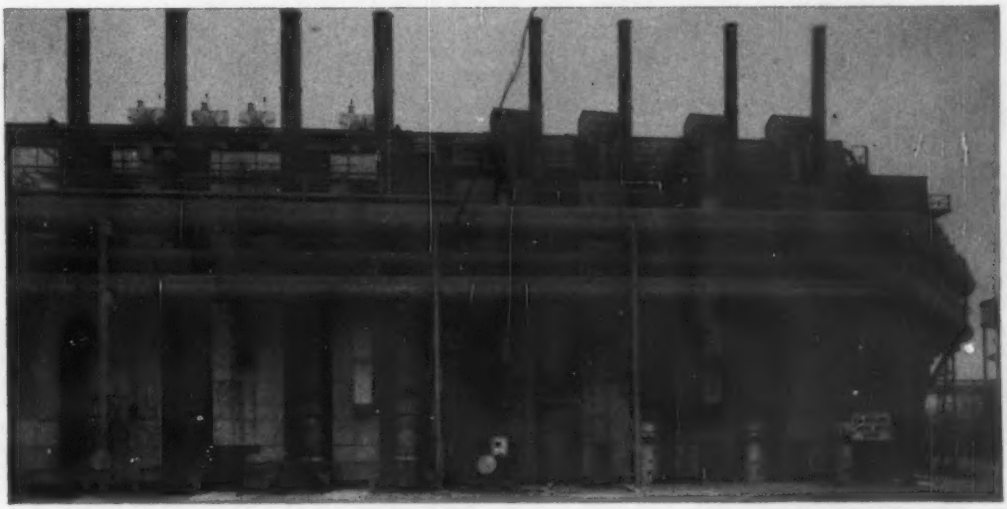

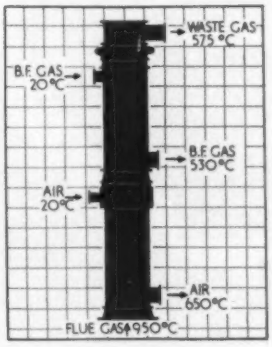

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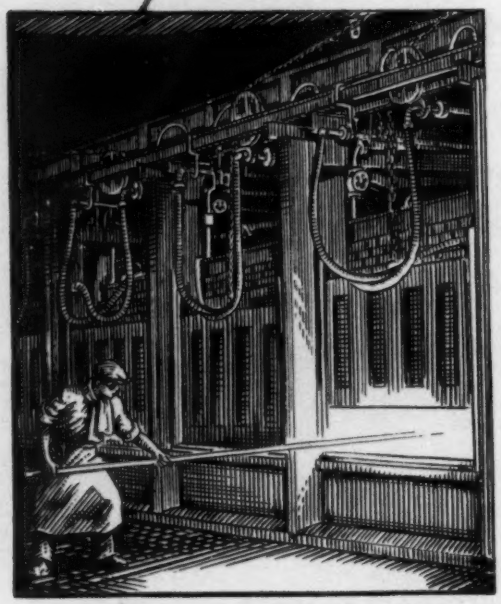

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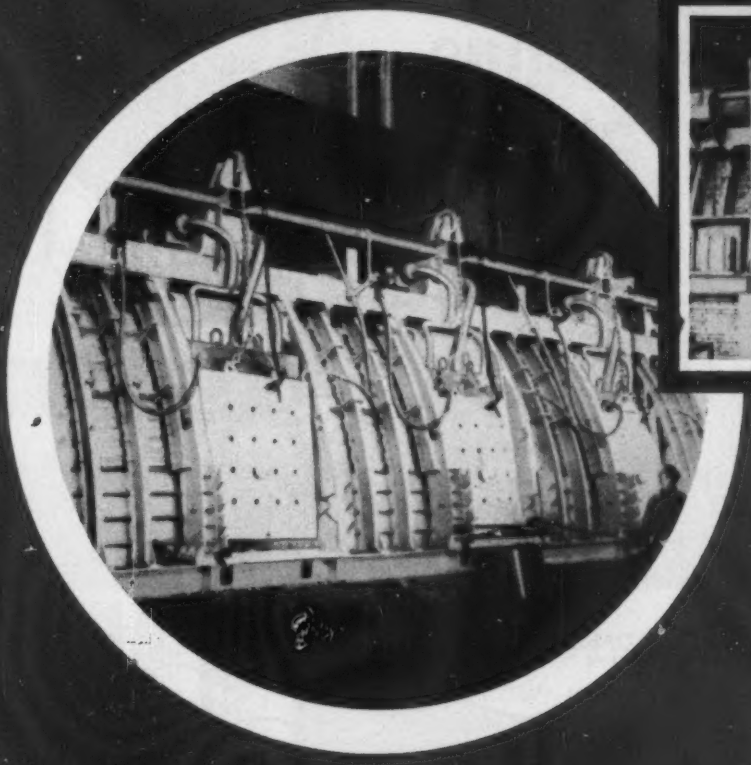

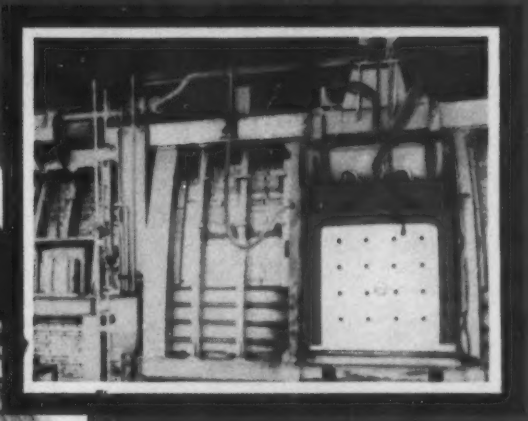

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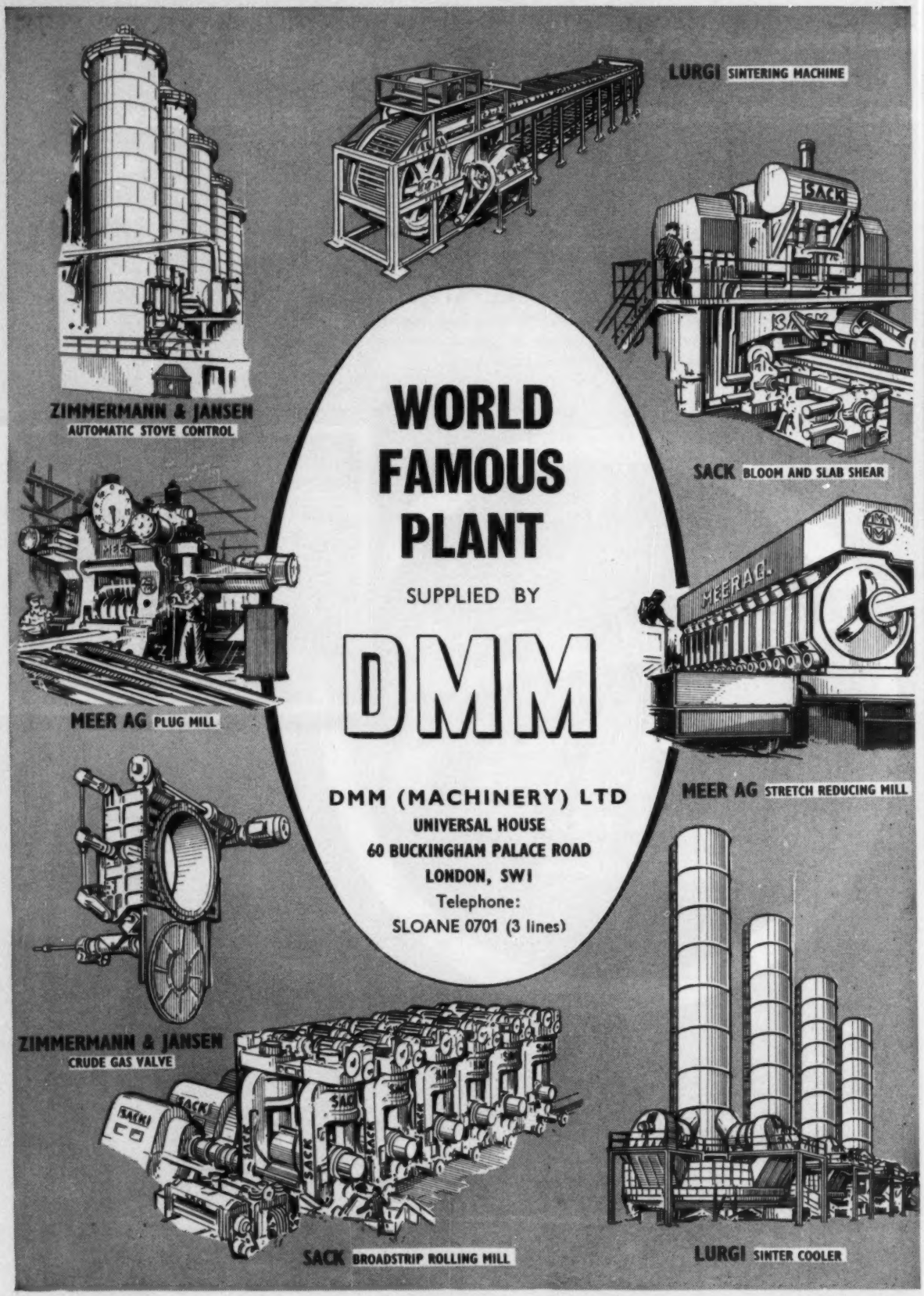
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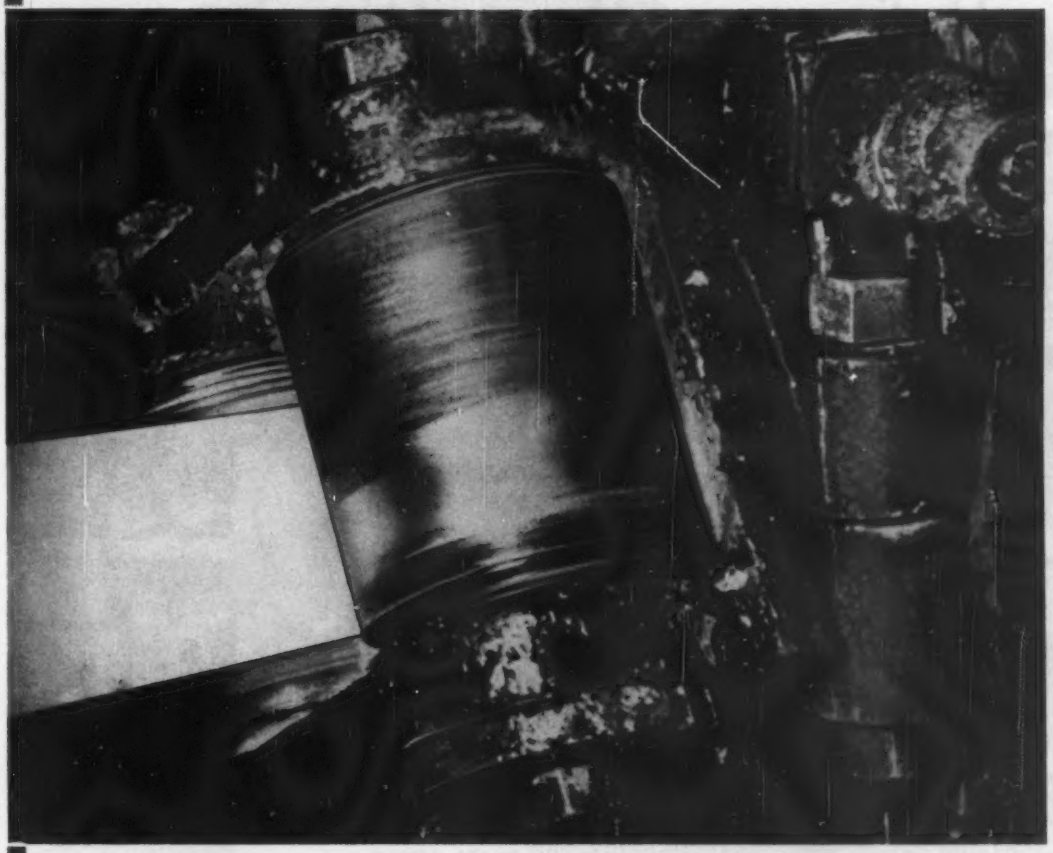

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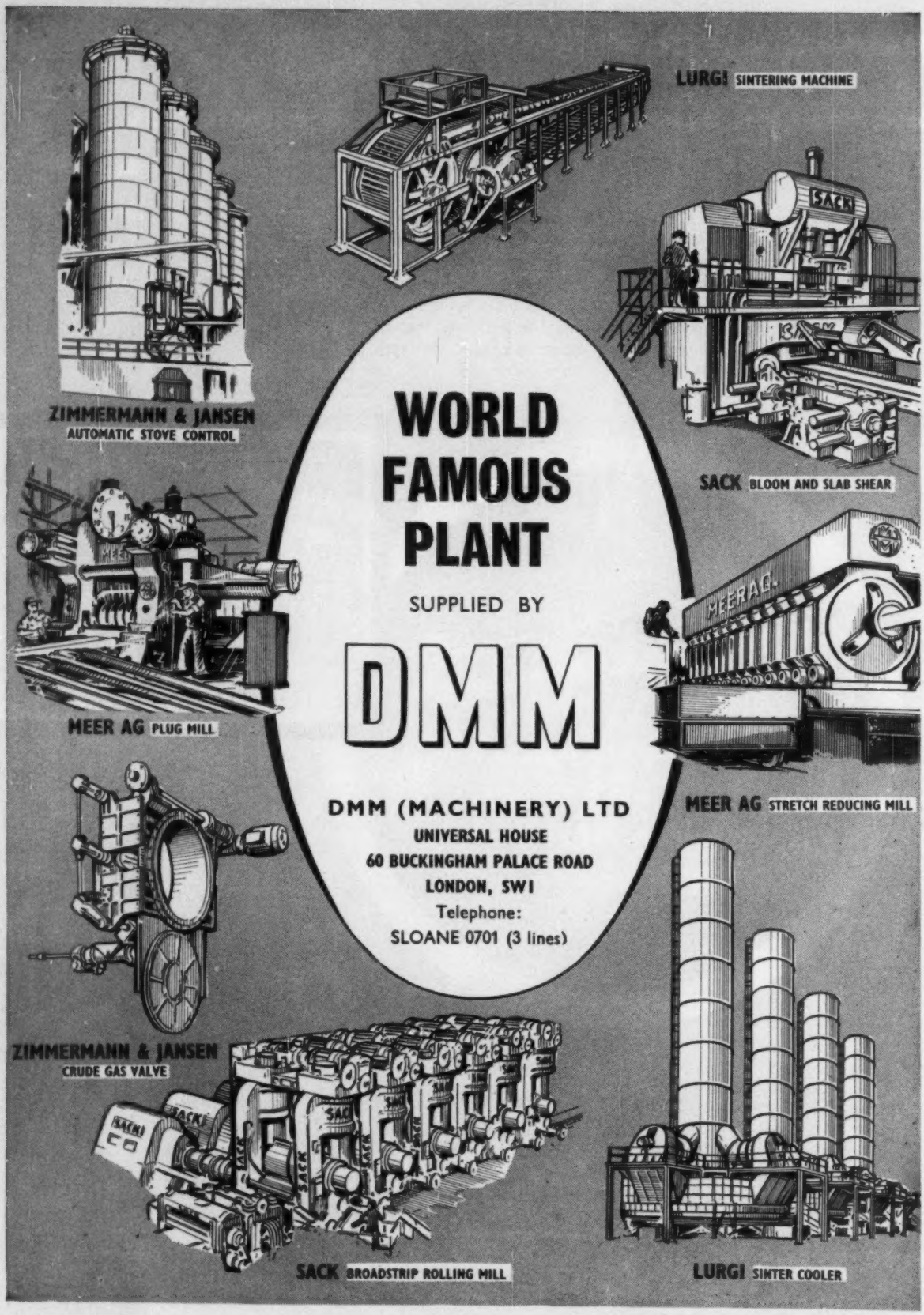
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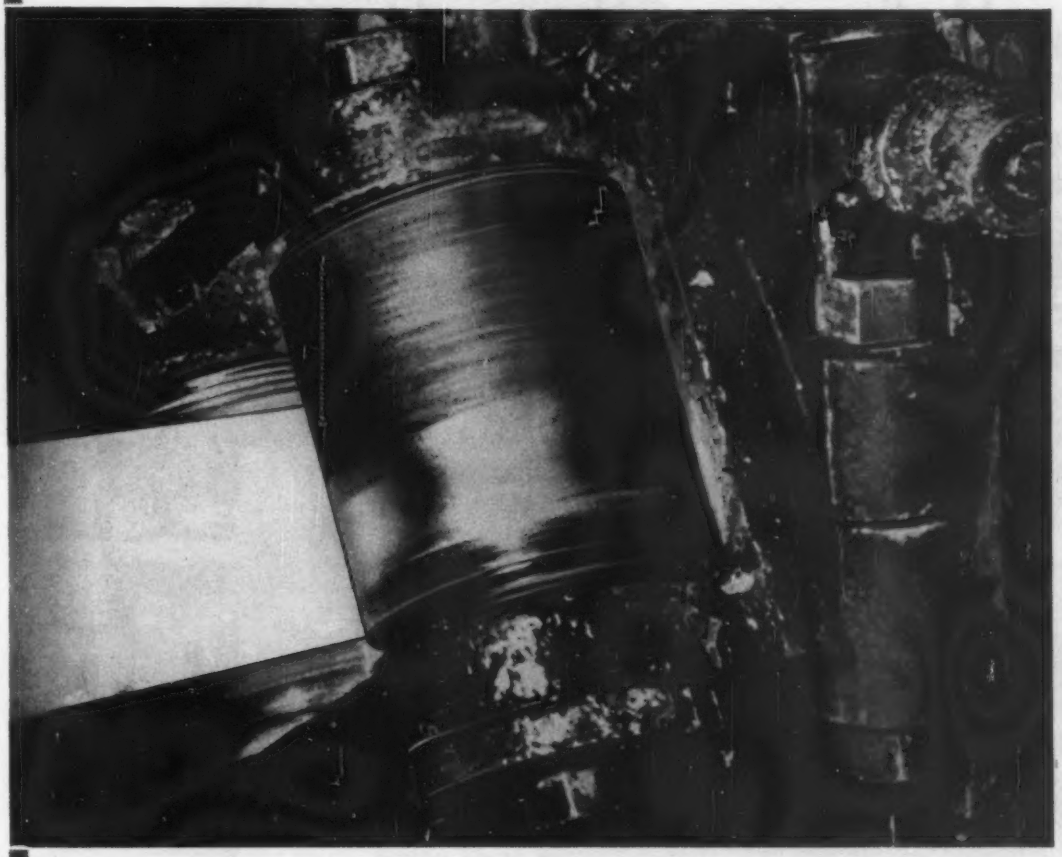

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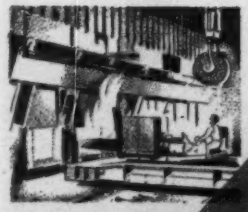

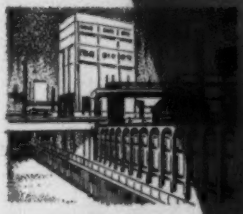
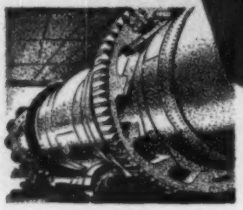

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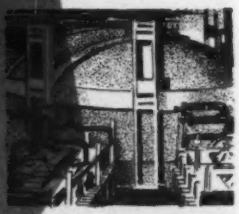

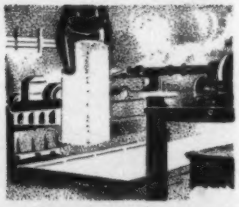
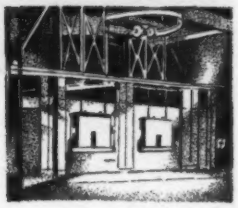

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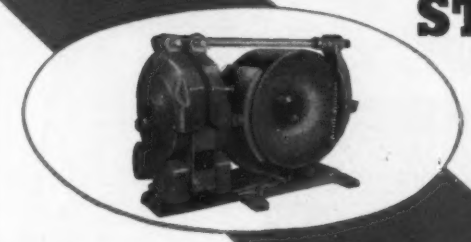

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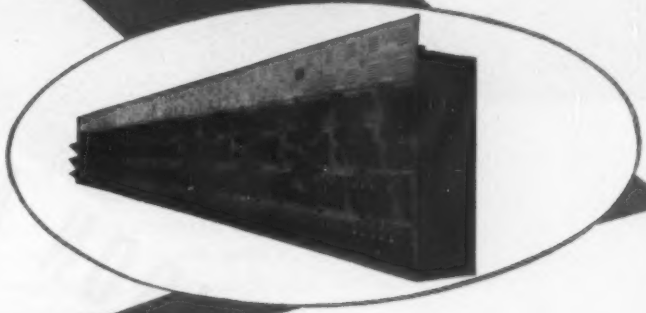

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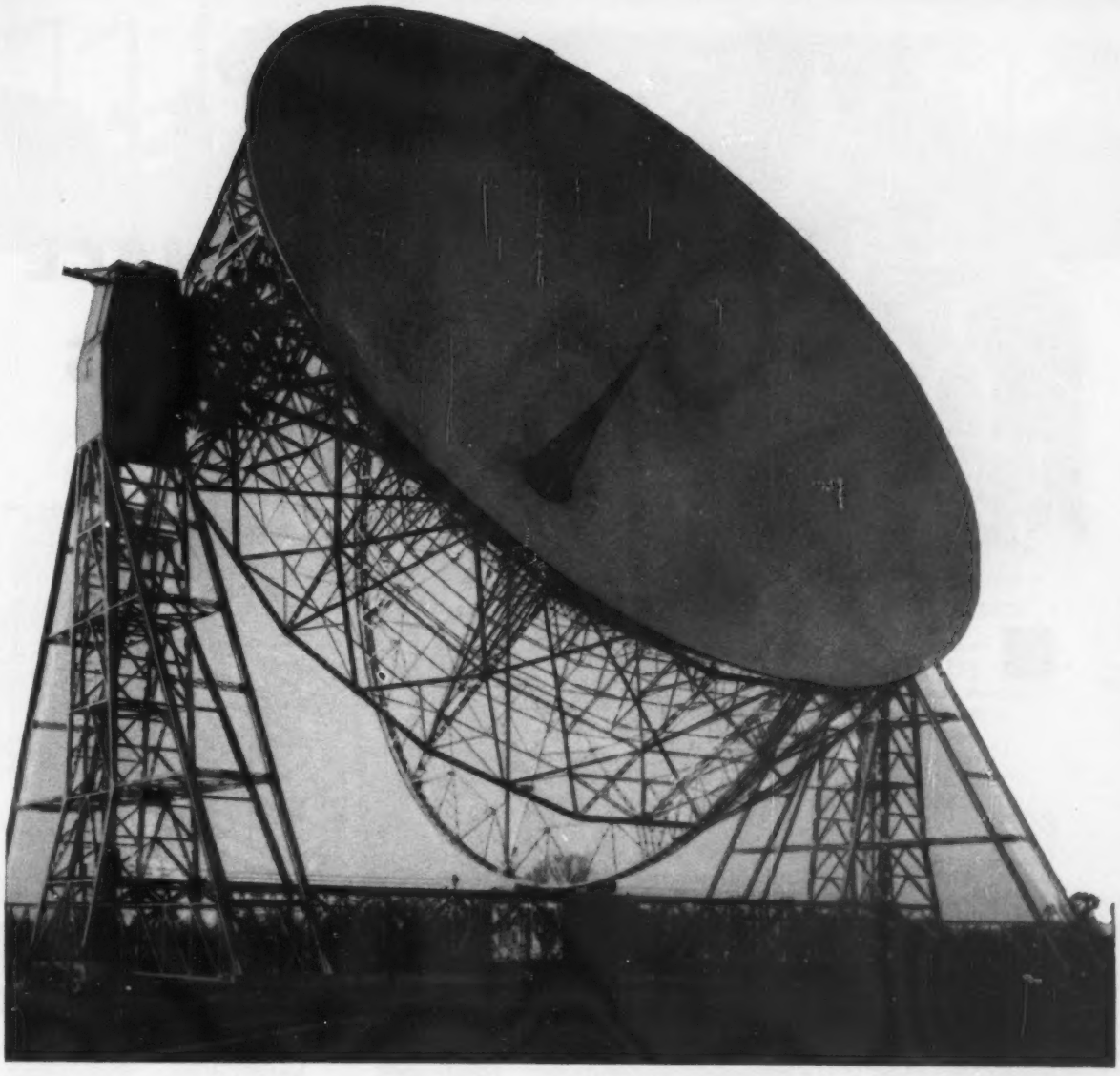

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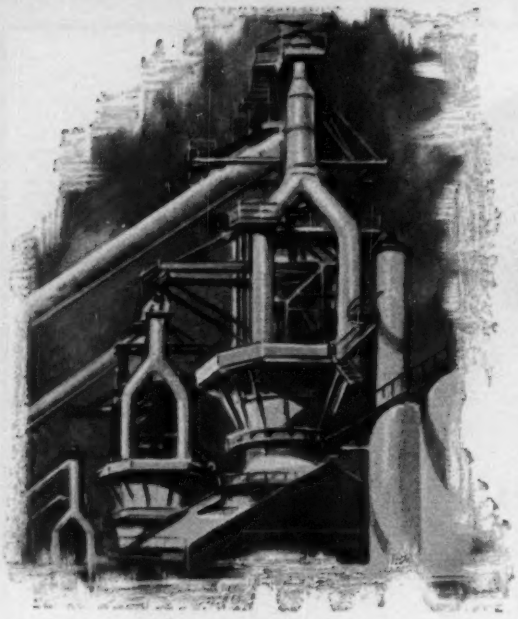

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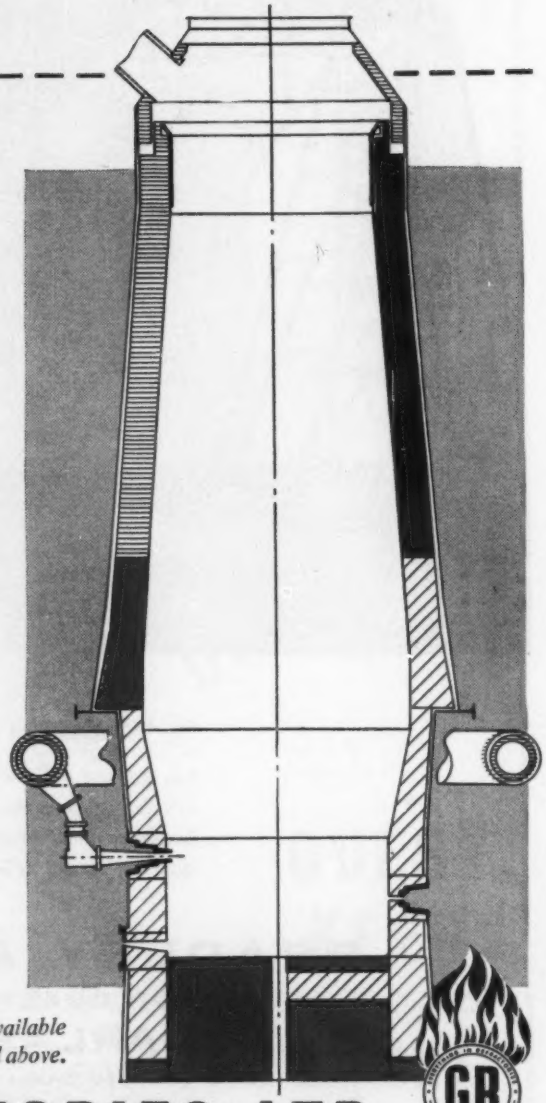

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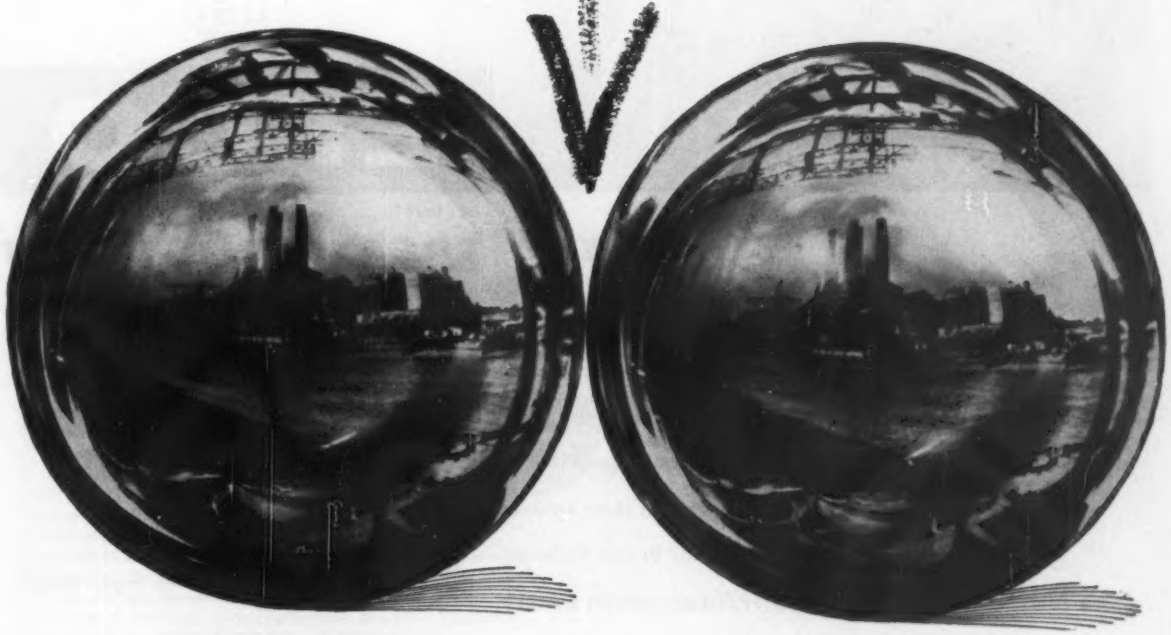

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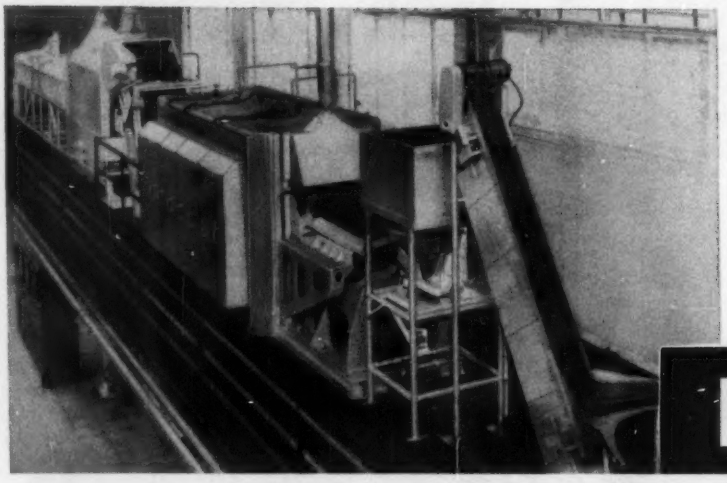

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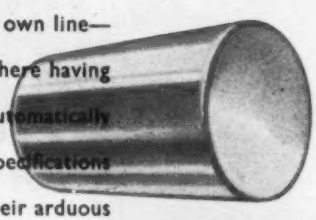

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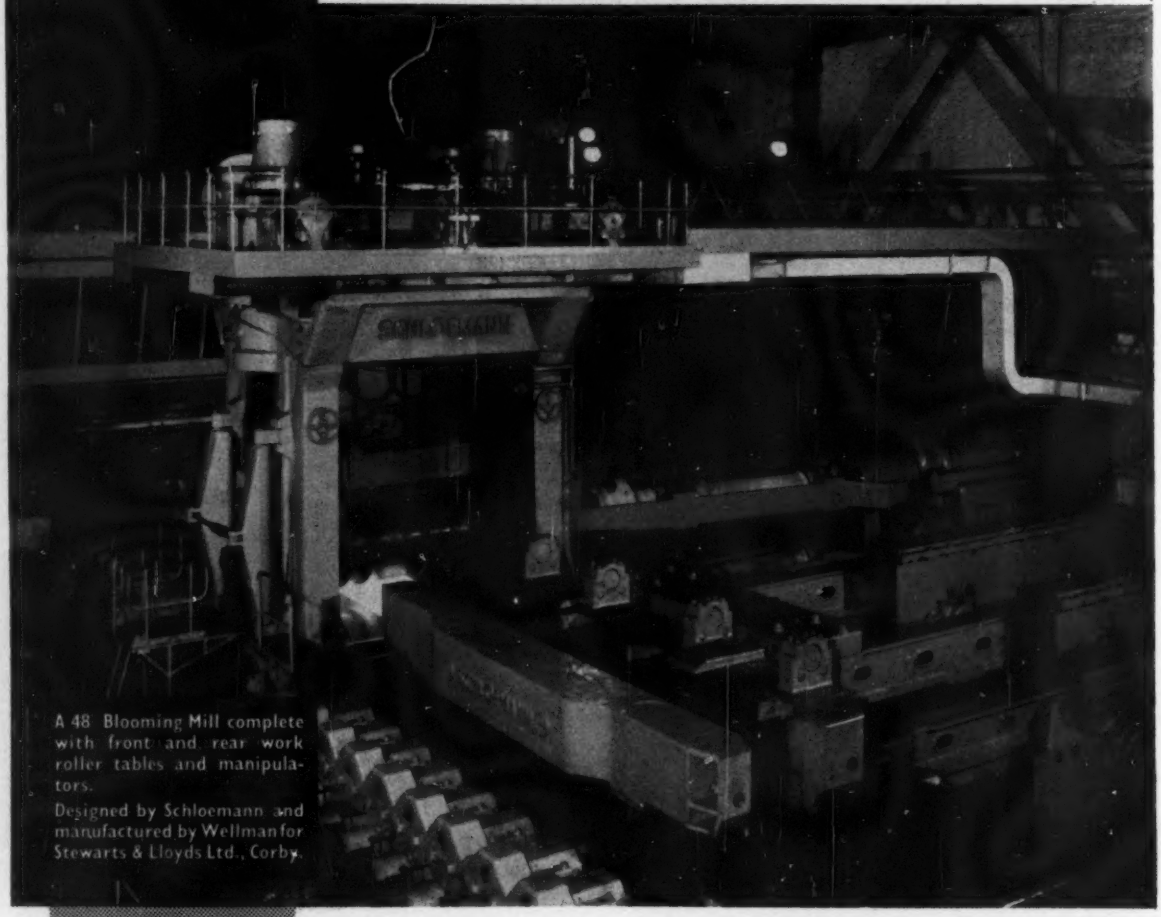

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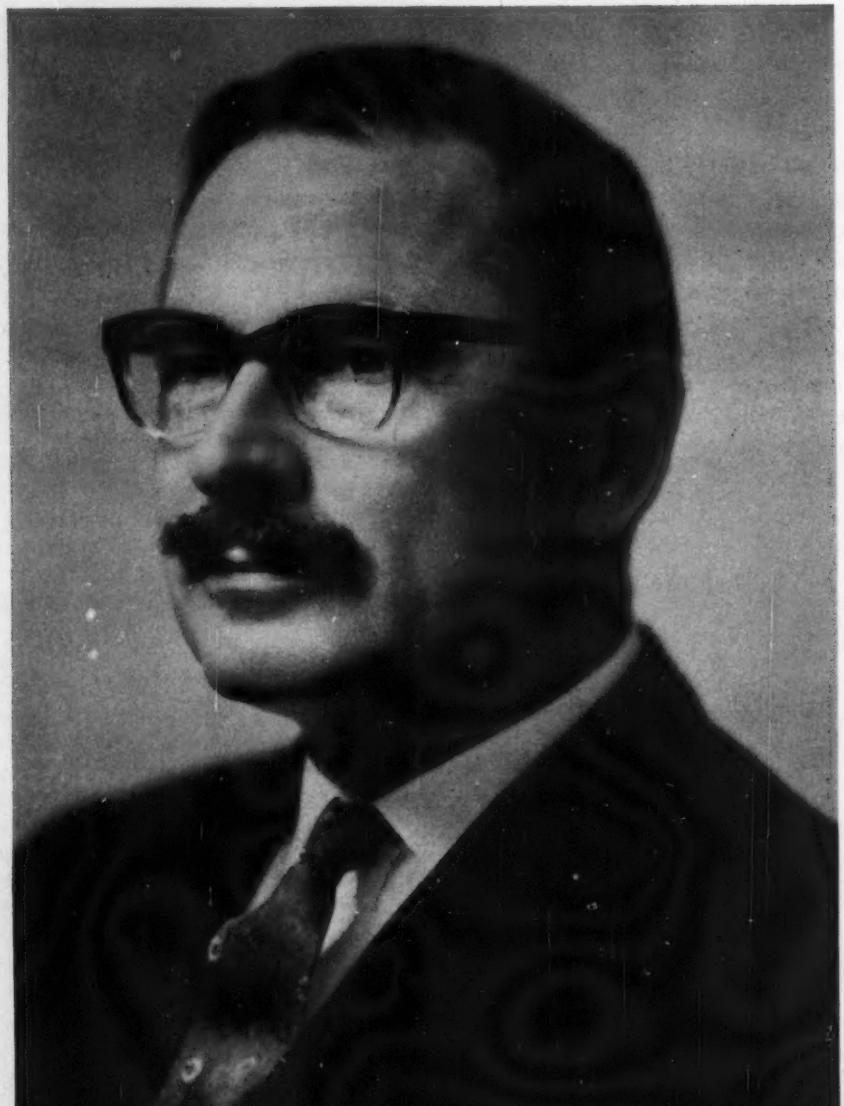
MAURICE ALBERIC FIENNES was born in 1907 and educated at Repton School and Armstrong College, Newcastle-upon-Tyne. He served an engineering apprenticeship with Ransomes and Rapier Ltd, Ipswich, and later joined the company's technical staff.

From 1930 to 1937 Mr Fiennes was manager of the pneumatic tool department at the Scotswood works of Sir W. G. Armstrong Whitworth and Co. (Engineers) Ltd in Newcastle-upon-Tyne. In 1937 he joined The United Steel Companies Ltd as commercial assistant to the managing director. He was later in charge of gun forgings and the gun departments of Steel, Peech and Tozer, and during this time he was responsible for liaison with and promotion of various other special armament activities within the United Steels group.

Mr Fiennes was with the Brush Electrical Engineering Company Ltd at Loughborough from 1942 to 1945 as general works director with special responsibility for the steam turbine division. In 1945 he was appointed managing director of Davy and United Engineering Company Ltd, Sheffield, and he is at present managing director of Davy–Ashmore Ltd, the plant engineering combine formed last year by the merger between Davy–United Ltd and The Power Gas Corporation Ltd, which includes the Stockton works of Ashmore, Benson, Pease and Company Ltd. During Mr Fiennes' association with Davy-United the company has expanded greatly and has actively participated in the development of the British iron and steel industry in the last decade, besides being associated with major overseas undertakings such as ISCON at Durgapur.

Mr Fiennes is a director of various companies associated with the Davy–Ashmore group. He joined The Iron and Steel Institute in 1946, and last year he was elected a Member of Council.



M. A. Fiennes, M.I.Mech.E.
Member of Council

Removal of scale from steel rod by stretching

K. Sachs and T. Pitt

SYNOPSIS

Steel rods of different carbon contents were oxidized for 5 and 20 min at 700°, 800°, and 900°C. They were stretched in a tensile machine and the scale that spalled off was weighed and screened. The influence of the independent variables, time and temperature of oxidation, and carbon content of the rod, on the weight of scale formed, amount and proportion of residual scale, and particle size of spalled-off scale, was assessed by the use of standard statistical techniques; the separate effect of each variable was determined and random scatter excluded. The total amount of scale and weight of adherent scale increased with time and temperature of oxidation, while the proportion of adherent scale was independent of these factors but tended to increase with carbon content; particle size of the spalled-off scale was independent of carbon content and duration of scaling but increased with temperature. A study of the direct interactions between the dependent variables, particularly the recognition of cause and effect, required a more empirical approach.

The weight of adherent scale and its proportion of the total decreased as the scale grew thicker. The flake size of spalled-off scale increased with scale thickness and oxidation temperature. There was no relation between scale adherence and particle size of spalled-off flakes.

Experimental evidence leads to the following view of the mechanism of spalling; a gap or plane of weakness is formed very close to the interface, perhaps towards the end of oxidation or more probably during cooling; when the rod is stretched, transverse cracks break up the outer scale into blocks which fall away; a very thin film of oxide remains attached to the metal together with isolated columns of oxide holding some blocks of thick scale to the adherent film. 1898

INTRODUCTION

THE SCALE FORMED on steel rod during hot rolling must be removed before the subsequent wire-drawing operation, otherwise excessive die-wear and scoring of the wire surface will occur. Removal is normally by pickling, but costs can be high, and disposal of spent acids presents many problems; the mechanical descaling process has therefore attracted commercial interests.

Mechanical descaling involves bending the steel wire round a series of pulleys before it enters the drawing die. Owing to the difference in ductility between the metal and its oxide, the scale cracks into flakes and spalls away from the rod. This often gives satisfactory, though incomplete, scale removal. The process has the advantage of being incorporated in the drawing operation, considerably reducing handling costs.

Unfortunately the small amount of scale remaining on the rod after mechanical descaling tends to score the wire-drawing dies. Improvements in the surface finish of mechanically descaled rod will reduce die wear and make the finished wire suitable for many applications at present reserved for pickled and limed wire. Attempts to remove the residual scale with rotating wire brushes or with abrasives have not been unequivocally successful.[1, 2, 3] A considerable body of opinion based on practical experience in the wire trade and on laboratory experiments suggests that the nature and structure of the scale on the hot-rolled rod determines how easily and how effectively it is removed in the mechanical descaler.[1, 2, 3, 4, 5, 18] A study of the mechanism by which scale spalls off the surface of the rod during plastic deformation and of the influence of easily controlled variables should make it possible to indicate the most desirable scale for mechanical descaling and to suggest how its formation is influenced by hot-rolling practice. Clearly, extensive research will be required before it is possible to improve the effectiveness of mechanical descaling by attention to the hot-rolling procedure. A first step is the study of wide variations in scale thickness and properties, if necessary by the use of furnace scales grown under laboratory conditions.

There appears to be a tendency for thick scales to be removed more effectively than thin ones.[1, 2, 18] This is probably due to the higher stress imposed on thick scales by bending over the pulley, but other factors must also play a part because the same trend has been detected in descaling experiments using tension.[5, 6] If spalling is caused by shear displacement at the scale/metal interface, then large flakes are more likely to spall than small ones[6]; the size of flakes is likely to increase with scale thickness.[1, 18] The present investigation was intended to establish whether there is in fact an effect of scale thickness on the scale retained after mechanical descaling and to study the influence of scaling time and temperature, and the carbon content of the steel, on descaling behaviour; the particle size of the scale removed by descaling was also measured in order to find out whether it bore a

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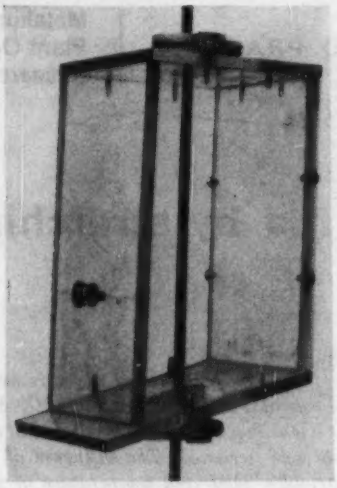


1 *Perspex box for collecting spalled-off scale* ×⅓ approx.

relation to the amount of scale retained. The mutual interactions of these variables were considered in some detail in an attempt to discriminate between possible spalling mechanisms.

So as to provide samples with a wide range of scale thickness it was necessary to oxidize clean lengths of rods for various times at various temperatures, instead of using hot-rolled rods. Every effort was made to produce scale resembling rolling scale in appearance and spalling behaviour, as far as possible. The results indicate the effects of controllable variables; they cannot be applied directly to the scales on hot-rolled products.

EXPERIMENTAL PROCEDURE

Preparation of scales

Commercially produced hot-rolled rods (5 swg wire-rod) with carbon contents of 0·05, 0·09, 0·19, and 0·49%, were mechanically straightened, pickled, and polished with 600 grade emery paper. This ensured a uniform initial surface condition throughout the samples. The scales were produced by soaking the rods for 5 or 20 min at temperatures of 700°, 800°, or 900°C, followed by air cooling.

Descaling procedure

A plastic extension of 8% was used throughout the experiments because it was known from published work[6,7] that an elongation of this order removes the bulk of the scale. The flakes of scale detached from the rod during plastic deformation were caught in a Perspex box (Fig.1). The box had $\frac{3}{16}$-in dia. holes drilled in its roof and floor so that a long rod could be pushed straight through. The rod samples were about 13 in long and were attached to the box by rubber seals held by 'Jubilee' clips. These supported the box on the rod during elongation and ensured that all, and only, the scale on the section of rod inside the box was collected. By making sure that the rubber seals were in contact with the outside edges of the box on assembling, a standard gauge length of 6½ in was obtained in all descaling operations.

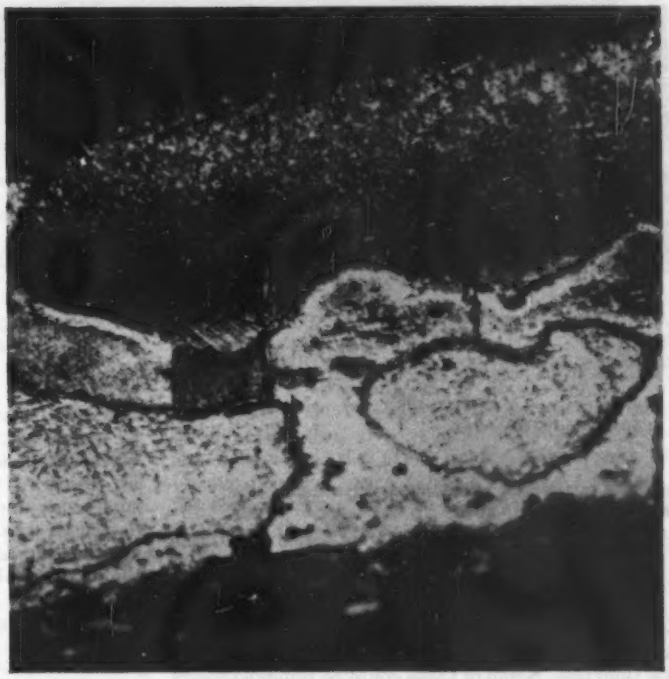
After 8% elongation any scale that still loosely adhered to the surface was brushed into the box and the total scale removed was collected. In many cases four samples of rods after identical treatments were descaled in order to obtain a sufficiently large, representative sample for particle size analysis.

Particle size analysis

The scale samples were vibrated in a nest of sieves on a standard sand-testing machine. A preliminary experiment indicated that the tendency to breakdown of the scale was very small indeed, and that between 10 and 15 min vibration gave reliable and reproducible results. The sieves used were British Standard screens having mesh numbers 8, 16, 44, and 150 respectively.

TABLE I Particle size analysis: Wt. and % on each sieve

	Mesh %C	>8 Wt	%	16 Wt	%	44 Wt	%	150 Wt	%	<150 Wt	%
20 min at 900°C	0·05	0·234	15·8	0·484	32·6	0·623	42·0	0·124	8·3	0·018	1·2
	0·09	0·050	4·85	0·292	28·5	0·560	54·5	0·117	11·35	0·010	1·0
	0·19	0·291	14·2	0·957	46·8	0·703	34·4	0·083	4·1	0·008	0·4
	0·49	0·020	3·0	0·172	25·9	0·384	57·8	0·078	11·7	0·011	1·7
20 min at 800°C	0·05	0·035	5·4	0·167	25·9	0·316	48·9	0·114	17·7	0·014	2·1
	0·09	0·146	15·6	0·406	43·1	0·274	29·2	0·095	10·1	0·021	2·2
	0·19	0·020	3·3	0·082	13·6	0·304	50·4	0·168	27·9	0·030	5·0
	0·49	0·010	5·4	0·020	10·9	0·068	36·9	0·070	38·0	0·016	8·7
20 min at 700°C	0·05	Nil		0·006	1·4	0·061	14·2	0·249	58·0	0·113	26·4
	0·09	Nil		0·016	5·0	0·097	30·4	0·157	49·3	0·049	15·7
	0·19	Nil		0·007	3·8	0·037	19·9	0·091	49·0	0·051	27·4
	0·49	Nil		Nil		0·024	28·6	0·041	48·8	0·019	23·7
5 min at 900°C	0·05	0·406	59·4	0·620	26·2	0·244	10·3	0·071	3·0	0·022	1·0
	0·09	0·861	42·3	0·647	34·1	0·348	18·4	0·106	5·6	0·006	0·3
	0·19	0·201	12·9	0·524	33·6	0·606	39·0	0·201	12·9	0·008	0·5
	0·49	0·140	8·6	0·670	41·6	0·622	38·2	0·153	9·3	0·020	1·2
5 min at 800°C	0·05	Nil		0·014	2·7	0·087	17·1	0·310	61·0	0·103	20·3
	0·09	0·004	0·8	0·066	11·5	0·200	38·1	0·212	40·5	0·047	9·0
	0·19	Nil		Nil		0·021	11·3	0·088	47·3	0·077	41·4
	0·49	Nil		0·006	3·8	0·026	16·6	0·073	46·6	0·052	33·0
5 min at 700°C	0·05	Nil		3 flakes		0·022	9·4	0·062	26·5	0·150	64·1
	0·09	Nil		3 flakes		0·021	9·4	0·078	34·8	0·125	55·8
	0·19	Nil		1 flake		0·008	3·6	0·084	37·7	0·131	58·7
	0·49	Nil		Nil		0·010	6·2	0·061	37·9	0·090	55·9



2 *Flake keyed firmly to the surface* × 12 approx.

After 12 min the amount of scale on each sieve was weighed. The results of this analysis are reproduced in Table I.

Examination and removal of the scale remaining on the rod after mechanical descaling

It would have been desirable to estimate the particle size distribution of the scale particles remaining on the rods. Unfortunately this was found to be impracticable and only the total weight of this adherent scale was determined. However, before this remaining scale was removed, a visual examination of each sample was carried out under a low-power binocular microscope. The adherent scale particles were then removed by a modified iodine extraction technique using a solution of 18% iodine in alcohol, double distilled over calcium. Two 5 in lengths of each sample were soaked in the solution in a thick-walled boiling tube for approximately 48 h, the spent solution being drawn off and replaced by a fresh one after 24 h.

The actual stripping operation was not carried out in a nitrogen atmosphere; this precaution is normally recommended[8] to keep oxygen out of the system and make absolutely sure than no oxidation takes place in solution. So as to strip all the required specimens in a reasonable time, boiling tubes with rubber stoppers were employed and the risk of slight oxidation accepted. It is extremely unlikely that the weight of residual scale has been appreciably affected, but the proportions of different phases may have been influenced to some extent.

After treatment the scale still attached to the rods was brushed into the tube and the solution decanted. The scale was thoroughly washed in clear industrial spirits and dried in an oven at 70°C. It was then removed from the tubes and weighed (results are given in Table II).

TABLE II Experimental results

Treatment	Steel, %C	Total scale per 1 in rod length W, g	Weight of scale remaining per 1-in rod length w, g	Mean particle size (mesh size passing 50% of scale) p (NAW)
20 min at 900°C	0·05	0·1178	0·0026	0·0587
	0·09	0·0838	0·0036	0·0523
	0·19	0·1580	0·0015	0·0675
	0·49	0·0579	0·0074	0·0495
20 min at 800°C	0·05	0·0515	0·0023	0·0483
	0·09	0·0752	0·0027	0·0680
	0·19	0·0466	0·0015	0·0398
	0·49	0·0171	0·0030	0·0295
20 min at 700°C	0·05	0·0180	0·0013	0·0145
	0·09	0·0138	0·0010	0·0190
	0·19	0·0112	0·0009	0·0154
	0·49	0·0044	0·0013	0·0182
5 min at 900°C	0·05	0·0923	0·0013	0·0950
	0·09	0·0749	0·0019	0·0840
	0·19	0·0619	0·0021	0·0573
	0·49	0·0646	0·0020	0·0605
5 min at 800°	0·05	0·0274	0·0014	0·0173
	0·09	0·0221	0·0015	0·0273
	0·19	0·0088	0·0017	0·0111
	0·49	0·0072	0·0012	0·0135
5 min at 700°	0·05	0·0066	0·0006	0·0067
	0·09	0·0066	0·0005	0·0088
	0·19	0·0061	0·0003	0·0073
	0·49	0·0046	0·0005	0·0078

EXPERIMENTAL RESULTS

Measurements of scale properties

From the available data a particle size distribution curve was plotted for each scale sample. The mean particle size of each sample was then read as that mesh size (measured in nominal aperture width) through which 50% of the scale would pass. The results are given in Table II.

3 *Loosely adherent scale on 0·19%C rod, oxidized for 20 min at 900°C and stretched 8%* ×1250

Visual and microscopic examination of the scale remaining after deformation

Mild steel and low-carbon steel rods scaled for 20 min at 800° and 900°C showed, after descaling, patches and sometimes quite large areas of very thin scale, covering in some cases up to 80% of the surface area. In addition, there were some small flakes of quite thick scale, which seemed to be remnant particles of the original scale thickness. Some of these could be removed easily with a fairly soft brush; others were more adherent. In addition there were isolated small blocks that seemed very firmly embedded in the surface in areas of uneven oxidation (*see* Fig.2). In cross-section, the surface of the descaled rod was largely bare; the adherent film that could be detected by direct examination was too thin to be resolved satisfactorily in the cross-section. A few pieces of scale could be observed here and there. They were mostly thick enough to correspond to the full initial scale deposit and consisted of wüstite with a relatively thin outer magnetite layer, consistent with normal scale growth at 900°C. In some cases (Fig.3), the scale was badly cracked and did not seem very firmly attached to the substrate; in others, the scale was sound and fully adherent (Fig.4).

Less severely scaled rod showed no evidence of uneven oxidation and no embedded blocks were found. Some quite extensive scale deposits had rather thick magnetite layers. That shown in Fig.5 was formed in 5 min at 900°C and its thickness was about half that of the scale on specimens oxidized for 20 min (*cf.* Fig.4); this is the theoretical ratio of thicknesses and suggests that both layers represent the full scale thickness. A rather thinner oxide film is shown, admittedly at a slightly lower magnification, in Fig.6; it consists predominantly of magnetite. Possibly this represents not the entire original scale, but an unusually thick inner film; the outer layer was presumably separated by a gap from this film and spalled off when the rod was stretched.

Another feature of these rods is illustrated in Fig.7. Deep depressions in the surface, rolling laps, and other defects, are filled with oxide. There may be a tendency for this firmly rooted oxide to hold some scale to the surface as appears to be the case with the smaller defect. It has been suggested that a rough surface after rolling favours the retention of oxide.[5] Even if the oxide breaks off level with the main surface of the steel, however, it may come into contact with the die in wire-drawing and cause scoring and wear.

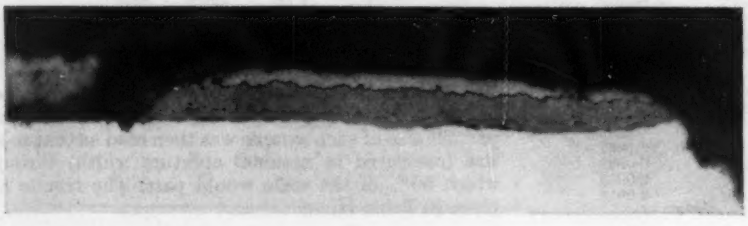
TABLE III Real interaction matrix

	C	t	θ	W	w	$f=w/W$	p
Carbon, % C		0	0	0 (1)	+ (2)	+ (4)	0 (6)
Time, t			0	+ (1)	+ (2)	0 (4)	0 (6)
Temperature, θ				+ (1)	+ (2)	0 (4)	+ (6)
Total scale weight (or thickness), W					− (3)	− (5)	+ (7)
Weight of adherent scale, w						+ (10)	0 (8)
Proportion of adherent scale, w/W							0 (9)
Particle size, p							

CONSIDERATION OF RESULTS

Interpretation of the experimental results

The experimental variables, time and temperature of oxidation, and carbon content of the steel, have a direct influence on the thickness of the scale formed. They may also affect the structure and mechanical properties of the scale and these in turn determine the amount of scale retained after plastic deformation. If the experimental results in Table II are to be used to assess the influence of scale thickness on the amount of oxide retained, this factor must be distinguished from the effects of the three independent experimental variables, which are themselves of considerable interest; interpretation is further complicated by the substantial scatter of results. By combining statistical analysis with direct physical interpretation of the results in Table II it has been possible to elucidate the main interactions between the experimental variables and the observed characteristics of the scale. Such an analysis is demonstrated in the Appendix; the conclusions reached are collected in a 'real interaction matrix' (Table III). The causal relations between any two factors are indicated at the intersections of the corresponding row and column. The absence of correlation is indicated by 0, changes in a common direction by +, and opposing ones by −; no attempt has been made to assess the strength of the correlation.



4 *More firmly adherent scale on similar rod* ×1250

5 *Scale on 0·19%C rod, oxidized for 5 min at 900°C and stretched 8%* ×1250

Summary of general conclusions

Descaling by plastic deformation is more effective the thicker the scale[1, 5, 6, 18]; if the effect of time and temperature on the scale thickness are allowed for, their independent influence on the scale properties tends to make it more adherent; increased carbon content of the steel has a similar effect.

The scale that spalls off during plastic deformation is broken up into coarser particles the thicker the initial scale layer[7, 18] and the higher the temperature of its formation. There is no direct evidence about the block size of the adherent scale, but the particle size of the spalled-off scale may be regarded as a crude indication of the likely size distribution; no correlation with the weight or proportion of adherent oxide could be detected.

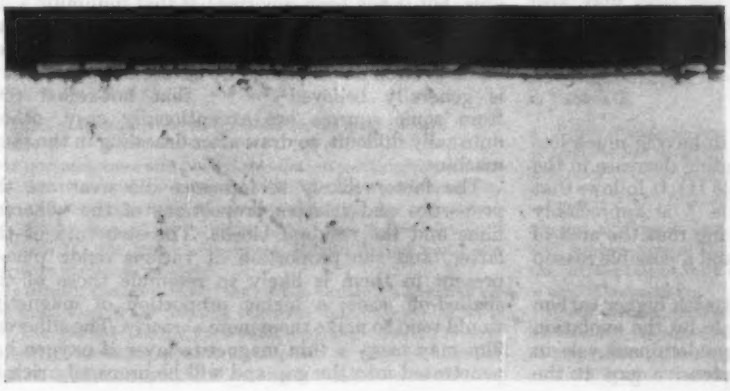
Mechanism of scale spalling

The scale on commercial steel mill products usually consists of a thin adherent inner layer separated by a gap from the bulk of the oxides.[10, 11] Cooling stresses,[16] various stresses building up in the growing scale,[9, 10] or the accumulation of vacancies at the scale/metal interface,[19] often lead to separation of fairly thick layers from the substrate, and in the final scale structure the phases are intermingled in a complex manner, owing to the penetration of oxygen into the gap under the scale.

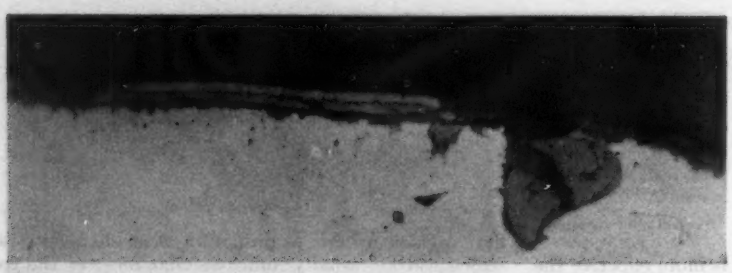
When the rod is stretched the metal deforms plastically while the oxide breaks in a brittle manner. Previous publications indicate that 78–98% of the scale is removed when the rod is deformed[1, 5, 6]; in the present work the range is 80·7–97·8% for low-carbon steels and 70·5–96·9% for steels with 0·49%C. It is possible that the scale separates from the rod at the metal/oxide interface, but that cannot be the only site of failure, because some scale is retained (*cf.* Figs.2, 4, and 8). A more likely plane of weakness is the gap between the bulk of the scale and the adherent oxide film. Metallographic examination of mechanically descaled rod[5, 11] usually indicates that most of the rod surface is bare down to the metal (as far as can be judged in the polished cross-section) and that the scale that is retained has the form of small blocks of appreciable thickness, generally consisting of all the layers present on a complete scale and often corresponding to the full thickness of the original scale (Figs.5–7). Some X-ray evidence in support of this observation has also been obtained.[6] It would seem, therefore, that the scale cracks transversely into blocks of various sizes and that these spall off as flakes, separating either at the metal/oxide interface or at the gap in the scale.

From the point of view of wire-drawing behaviour the most important question to be answered concerns the character, quantity, and properties of the oxide remaining on descaled rod. Thus it is of some practical interest to find out whether the remaining oxide consists predominantly of thick blocks or of a thin film covering most of the surface.

If the weight of residual scale (w) represents mainly a thin adherent film, it will depend on the thickness of the film, i.e. the location of the gap in the original scale. However, the results in Table III indicate that w diminishes as the total scale weight (W) increases; this would imply that the gap is formed closer to the interface the thicker the scale layer, which seems highly improbable. It follows that small adherent blocks form a significant or even predominant part of the residual scale w; increase in the total scale weight W would give thicker blocks and can lead to a decrease in their weight w only if the area of adherent blocks shrinks faster than their thickness grows. It follows that the number or size of oxide columns across the gap diminishes with scale thickness. The effect of carbon content of the steel on scale adhesion suggests that it favours the persistence of such oxide columns or 'bridges'.



6 *Thinner oxide film on similar rod* ×850



7 *Oxide in rolling defects* ×850

DISCUSSION

Bridges

Separation of the scale from the substrate slows down oxidation of the metal beneath the gap and the overall rate of scaling is maintained by continued oxidation elsewhere, in areas where the scale remains adherent. An extensive gap must lead to intermittent healing and the formation of a spongy inner scale layer. In the present work, however, the scales on the mild steel specimens were substantially compact, yet the gap extended over such a large proportion of the interface area that the bulk of the scale spalled off on stretching. This can best be explained by separation of the scale from the substrate during cooling, rather than as part of the oxidation mechanism.[16] If this is the case, bridges represent areas where this separation has not occurred, either because cooling stresses are less severe or because the material at the interface can withstand them better. It has been suggested that the formation of magnetite at the metal/oxide interface, which has been observed on hot-rolled material, may be initiated by compressive stresses in the wüstite and may tend to relieve them.[11] Thus, magnetite formation and lateral cracking are alternative methods of accommodating the stress. If cracking occurs, the scale separates from the metal and a very thin oxide film forms in the remainder of the cooling cycle; if magnetite is formed, the scale remains attached to the metal. Thus, bridges may represent areas where a magnetite seam has formed at the interface and factors favouring this mode of wüstite decomposition will tend to increase the total bridge area. An adherent block of oxide with magnetite at the interface is shown in Fig.8.

The stress in the scale is presumably higher when the scale is thicker and this may encourage cracking and reduce the bridge area. It has been suggested[11] that the presence of carbon in the steel may also nucleate magnetite formation and this may account for the tendency of the bridge area to increase with carbon content.

Steel with 0·49%C

This steel differs from the others in having much less total scale W without a corresponding decrease in the weight of adherent scale w (*cf.* Table II). It follows that the proportion of adherent scale f is appreciably higher than in other steels, implying that the area of the bridges is appreciably larger, and a possible reason for this has been indicated.

It seems possible, however, that with higher carbon contents the disruption of the scale by the evolution of carbonaceous gases[15] plays a predominant role in the mechanism of scaling. An extensive gap at the interface, together with rapid healing of transverse fissures in the outer scale layer, could account for the appreciable decrease in oxidation. In such circumstances the inner scale layer could well be spongy[19] and mechanical failure on stretching might occur within the spongy scale.

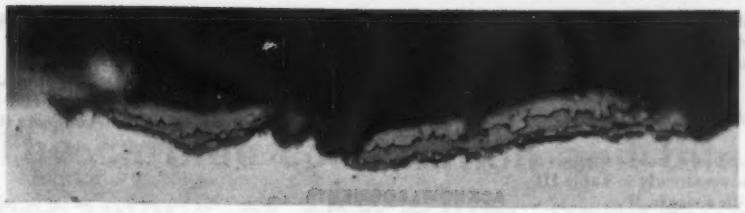
It seems possible, therefore, that the scale on steels with carbon contents of the order of 0·5% spalls in a different manner from that on mild steel. The adherent shell beneath the gap is porous and much thicker; nevertheless blocks of the outer layer remain attached to it and spall off more readily the thicker the total scale.

Effect of scale on die wear

The particle size of the scale that spalls off when the rod is stretched is apparently not relevant to the mechanism of scale removal. However, it throws an interesting light on the mechanical properties of the scale. If the scale cracks in a brittle manner the strain imposed in stretching will open up Griffith crack nuclei and these will grow until the scale fails transversely. For a given strain in the rod, the stress in the scale will be less severe the thicker the scale, so that fewer nuclei will operate and fewer cracks will form; naturally, the coherent blocks between the transverse cracks will be larger. Increase in temperature also leads to a larger particle size of the descaled oxide and this points to a smaller number of nuclei large enough to be activated by any given stress, corresponding to an increase in the inherent brittle strength of the scale.

The residual scale is believed to be responsible for increased die wear in the wire-drawing of mechanically descaled rod, although other contributory factors have also been mentioned in the literature.[7,18] Very little information about the effect of different types of scale on ease of removal and subsequent die wear is available, but it has been reported[1,18] that minimum scale is not invariably associated with minimum die wear, that a high proportion of magnetite in the descaled oxide is often accompanied by severe die wear, and it is generally believed[1,2,3,4,5] that hot-rolled rods from some sources are exceptionally easy, others unusually difficult, to draw after descaling in the same machine.

The factors likely to influence die wear are the properties and relative proportions of the adherent films and the residual blocks. The structure of the latter, and the proportion of various oxide phases present in them is likely to resemble those of the spalled-off scale; a higher proportion of magnetite would tend to make them more abrasive. The adherent film may carry a thin magnetite layer if oxygen has penetrated into the gap and will be unusually rich in



8 *Adherent scale on hot-rolled rod after 10% deformation* ×1250

magnetite if it has formed in cooling.[18] In some cases, therefore, the adherent film may be more abrasive than the thick blocks and this may account for cases of severe die wear in spite of relatively small amounts of residual scale.

If a higher temperature of oxidation increases the mechanical strength of the residual blocks it may also make them more abrasive. More precisely: the final particles produced by the stresses will be coarser. These would be dragged through the die and would increase die wear. This suggests that high temperatures of hot rolling may lead to greater difficulty in the drawing of mechanically descaled rod; it would be interesting to compare this deduction with practical experience but care must be taken to keep other factors constant: for instance, higher rolling temperature will produce a thicker scale and thus reduce the amount of residual oxide.

APPENDIX

Statistical analysis of the results

The probability that two sets of figures are interrelated can be expressed statistically by correlation coefficients, which can be tested for significance, i.e. by discovering whether the deviation from zero can be accounted for by the variance of the experimental results. Full correlation coefficients refer to the relation between any two factors, regardless of variations of other factors, while partial correlation coefficients indicate the degree of the relationship when all other factors are held constant. Both full and partial correlation coefficients were determined for the experimental results in Table II.

It was necessary in some cases to overcome the excessive rigidity of partial correlation coefficients where all extraneous variables are fixed by the use of 'intermediate partial correlation coefficients' where only some of them are held constant but the principal variables retain one or more degrees of freedom. By the use of these methods the causal relations between the variables have been elucidated qualitatively and summarized in a 'real interaction matrix' in Table III. The absence of a significant relation is indicated by a 0; positive and negative correlations are shown by the appropriate signs. The detailed reasoning leading to the various correlations is presented below and the number of the relevant paragraph is marked at each intersection in Table III. It was taken as axiomatic that there could be no causal connexion between the independent variables (θ, t, and C).

1. Effect of the independent variables on the total amount of scale W

Both commonsense and partial correlation coefficients indicate that the relationships between scale thickness and temperature and between scale thickness and time are significant (at 5%): ($r_{Wt.\theta C_{wp}} = +0{\cdot}6324$ and $r_{W\theta.tC_{wp}} = +0{\cdot}6592$). In Table III the relations between W and both θ and t are therefore shown as positive.

As regards the influence of the carbon content of the steel on the amount of scale formed, both the full ($r_{WC} = -0{\cdot}2412$) and the partial ($r_{WC.\theta t_{wp}} = 0{\cdot}2622$; $r_{WC.\theta t_p} = -0{\cdot}0823$) correlation coefficients are not significant. A very pronounced drop in total scale weight W in the 0·49%C steel is obvious from Table II but it has evidently been masked by random scatter at lower carbon levels.

2. Effect of the independent variables on the adherent scale w

The influence of both time and temperature on the weight of scale remaining on the surface after plastic deformation is demonstrated by highly significant full and partial correlation coefficients. Accordingly, the interactions between w and both θ and t are positive in Table III.

The effect of carbon is less clearly defined. Both full and partial correlation coefficients are not significant. However, θ and t have such a strong effect on w that it may not vary at all when these factors are held constant; it is possible that when θ and t are free, the variation in w is related to the carbon content of the steel. In fact, $r_{wC.W} = +0{\cdot}3794$, which is significant at the 5% level. This indicates an interaction between carbon content and residual scale and Table III is marked accordingly.

3. Effect of original scale weight W on the adherent scale w

The full correlation coefficient suggests that the amount of adherent scale increases with scale thickness ($r_{wW} = 0{\cdot}3561$ 10% significant), but since both these variables increase with time and temperature, this relationship may be spurious. The partial correlation coefficient indicates even more strongly that the amount of adherent scale diminishes as the scale grows thicker ($r_{wW.\theta tC_p} = -0{\cdot}4854$, significant at 5% level), but since there are no degrees of freedom left, this may apply only to the random fluctuations of the two variables. In this context the intermediate correlation coefficients are especially useful; they were selected to leave as much scope as possible for variation in the original scale weight W:

$r_{Ww.t} = 0{\cdot}274$ (not significant); $r_{w.W\theta} = -0{\cdot}227$ (not significant); $r_{wW.\theta t} = -0{\cdot}618$ (significant at 5% level).

Evidently, growth in scale thickness due to a rise in temperature or time of oxidation is accompanied by an increase in the amount of scale retained on the surface after stretching (Table II). When the time of the oxidizing treatment is held constant, and the amount of scale formed varies primarily as a function of temperature, the positive correlation coefficient becomes much smaller and ceases to be significant. When the temperature is held constant the coefficient becomes negative, and when the time also is constant, the negative coefficient is numerically large enough to be significant. This shows that the apparent correlation between w and W is due to their common dependence on θ and t. The real causal connexion between them is revealed when θ and t are held constant. The coefficients for these conditions are negative, and the conclusion that the thicker the original scale the less oxide adheres after plastic deformation is recorded in the real interaction matrix in Table III.

4. Effect of independent variables on the proportion of adherent scale ($f = w/W$)

The intermediate coefficients with W held constant:

($r_{ft.W} = 0{\cdot}30$; $r_{f\theta.W} = 0{\cdot}15$)

are not significant and indicate that the variation with time and temperature of the proportion of the scale remaining on the surface can be fully accounted for in terms of variations of w and W separately.

Since carbon content has no significant effect on W but increases w, its effect on the ratio between them is also likely to be positive. The partial correlation coefficient is significant at the 5% level, and the intermediate coefficient $r_{fC.W} = 0{\cdot}598$

is also highly significant. Evidently there is an increase in the residual scale fraction with rising carbon content in the steel; the effect of a carbon content as high as 0·49% is in fact obvious from Table II.

5. Effect of the amount of original scale W *on the residual fraction* ($f=w/W$)
The ratio $w:W$ must decrease as W increases, unless there is a corresponding rise in w; it has been shown already in Table III (*see* above) that in fact w decreases with a rise in W.

It follows that increase in scale thickness must lead to a reduction in the fraction of adherent scale and this is recorded in Table III.

6. Effect of independent variables on the particle size p of the scale removed by plastic deformation
There is no effect of time or carbon content. The particle size increases at higher oxidation temperatures; this is confirmed by both full and partial correlation coefficients and by intermediate coefficients:

$r_{p\theta.W}=+0{\cdot}4830$; $r_{p\theta.tC}=+0{\cdot}8584$

7. Effect of total weight of scale W on particle size p
The full correlation coefficient is positive and highly significant. However, both total scale weight and particle size increase with temperature. The intermediate coefficient with θ held constant

($r_{pW.\theta}=0{\cdot}5482$ significant at 5% level)

proves that the increase of particle size with scale thickness, is real.

8. Relation between particle size p and the residual scale w
The relationship $r_{wp}=+0{\cdot}4007$ (significant at 5%) suggests that the amount of adherent scale increases as the particle size increases, but both factors increase significantly with temperature. The intermediate partial correlation coefficient calculated with temperature constant ($r_{wp.\theta}=-0{\cdot}1870$) is not significant, and suggests that the relationship is not real.

9. Relation between particle size p and the residual scale fraction ($f=w/W$)
The full correlation coefficeint is significant ($r_{fp}=-0{\cdot}5393$). However, particle size increases with the total weight of scale, while the fraction of residual oxide diminishes; an increase in W would raise p and lower w/W, so that the negative correlation could be spurious. That this is the case is shown by the intermediate coefficient for constant W ($r_{fp.W}=-0{\cdot}0738$), which is not significant. It is concluded that no real interaction exists between p and w/W, and this has been recorded in Table III.

10. Relation between the weight w and proportion ($f=w/W$) *of adherent scale*
No correlation coefficients have been estimated. However, it has been shown that increase in w is associated with a decrease in W; it follows that there must be an even sharper rise in w/W. Table III has been filled in accordingly, to complete the interrelation matrix.

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The carbide constitution and tempering behaviour of chromium–vanadium–niobium steels at 700° C

K. C. Mills, B. B. Argent, and A. G. Quarrell

SYNOPSIS

The carbide constitution and tempering characteristics of chrome–vanadium steels containing 0·2% and 1·0%Nb have been determined. It is suggested that the niobium additions reduce the carbon available for combination with iron, chromium, and vanadium and that these changes in the effective carbon content have caused the observed movement of the carbide phase boundaries.

1886

INTRODUCTION

THE CREEP PROPERTIES and various other physical properties of alloy steels are dependent upon the nature and distribution of the carbide, nitride, and intermetallic phases present. Several workers have correlated the physical properties of steels with their alloy content and with the carbides present. These investigations led to the development of ferritic creep-resisting steels containing 0·2%C–Cr–V and various other alloying elements.

Shaw and Quarrell[1] investigated the carbide constitution at 700°C of 0·2%C–Cr–V steels ranging in composition from 0–12%Cr and 0–2%V. In cases where carbide transformations occurred, the approach to equilibrium was also studied. Later Smith and Quarrell[2] investigated the effect of molybdenum on the carbide constitution of similar steels at 700°C. The present work has been concerned with the effect of niobium, a strong carbide-forming element, on the carbide constitution and the tempering characteristics of Cr–V steels. Attention has mostly been limited to steels containing 0·2 or 1·0%Nb.

EXPERIMENTAL

Preparation of steels

Previous workers[1,2] prepared air-melted alloys in an 18 lb induction furnace and steels 1–8 of the present investigation were cast in this manner. The nitrogen contents of these steels were high; in the range 0·02–0·04%, and so the remainder were vacuum cast in a 28 lb Efco Edwards vacuum induction melting unit. Nitrogen contents of ~0·006% were obtained; about the same as in industrial practice. Steels 59–101 were 28 lb melts cast into a 3-in square chilled mould and steels 130–230 were 14 lb melts cast into two 7 lb moulds tapering from 2 in square at the top to 1 in at the bottom. All the ingots were soaked at 1200°C and forged to 1 in bar. After metallographic examination, twice the apparent depth of decarburization was machined off the forged bar.

Heat-treatment of steels

After a preliminary series of experiments the following standard heat-treatment was used for all the steels. 3 in specimens about $\frac{3}{4}$ in dia were soaked for 4 h at 1300°C, followed by $\frac{1}{2}$ h at 1150°C and then quenched into iced 9% brine. Tempering treatments at 700°C were carried out in lead baths, which employed a coal gas atmosphere to prevent oxidation.

Examination of the carbide phases

The carbides were extracted electrolytically using a cell developed by Smith and Quarrell.[2] An electrolyte of 15% sodium citrate, 1%KCNS, 0·05%HCl, 0·02% formaldehyde is used and a current density of 0·025 A/cm^2 was maintained for 30 h. The carbide particles were separated by centrifuging the used electrolyte and they were then washed with distilled water, alcohol, and ether, and allowed to dry.

The carbide residues were chemically analysed for Cr–V–Fe–Nb–Ta. The Cr–V–Fe contents were determined using standard techniques for steel analysis. The Nb plus Ta content was determined gravimetrically[3] and the niobium content was found colorimetrically.[4] Tantalum contents were obtained as the difference of these two figures.

Previous workers[1,2,5] have shown that carbon analysis is unsatisfactory, as decomposition of the carbide occurs during extraction and results in an apparent carbon content greater than the true value. All of the analytical data have therefore been expressed in metal–atom ratios, e.g. chromium metal–atom ratio is:

$$\frac{\frac{Cr\%}{52{\cdot}01}}{\frac{Cr\%}{52{\cdot}01}+\frac{V\%}{50{\cdot}95}+\frac{Fe\%}{55{\cdot}85}+\frac{Nb\%}{92{\cdot}91}+\frac{Ta\%}{180{\cdot}8}}$$

The carbides were identified by X-ray examination using CoKα or unfiltered chromium radiation. In the earlier stages of the work a 9 cm Metropolitan-Vickers powder camera was employed but in the later stages a Guinier focusing camera was used with great success

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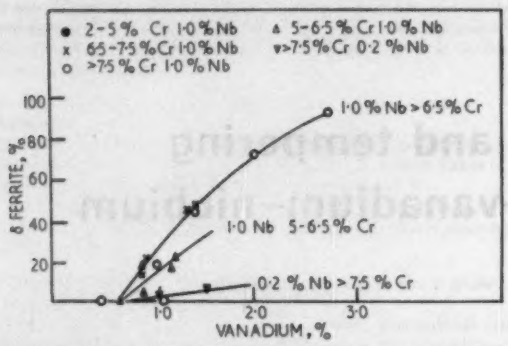
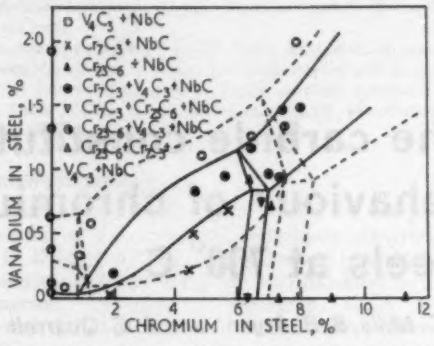
Dr Mills was formerly a research student in the Department of Metallurgy, University of Sheffield, and is now at the Carnegie Institute of Technology. Professor Quarrell and Dr Argent are at the Department of Metallurgy, University of Sheffield.



1 *Relationship of the amounts of δ ferrite to the composition of the steels*



3 *The carbide constitution at 700°C of 0·2%C, 1·0%Nb Cr–V steels*

for the identification of carbides present only in trace quantities.

Metallographic examination of the steels

Specimens for optical and electron metallographic examination were prepared by wet grinding on silicon carbide papers (220 C–600 A) followed by electropolishing in an electrolyte of 950 ml glacial acetic acid and 50 ml perchloric acid. The conditions for electropolishing varied with the steel composition but the applied voltage was kept between 55–75 volts and the polishing time was between 55–70 s. Finally the specimens were etched in Villelas Reagent.

The amount of δ ferrite was determined by the use of a Swift semi-automatic point counter fitted to a Watson microscope.

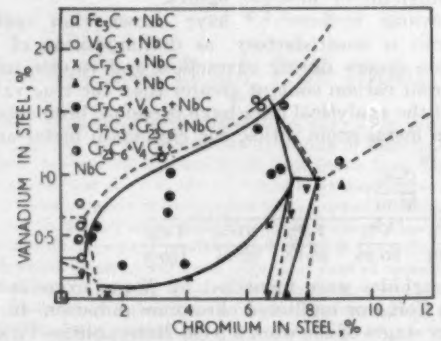
Carbon extraction replicas were prepared for electron microscopy using a secondary etchant of 5% nital or 5% bromine in alcohol. The replicas were examined at various magnifications on a Metropolitan-Vickers EM3 microscope.

SOLUTION TREATMENTS FOR CARBIDES IN 0·2%C, Cr–V–Nb STEELS

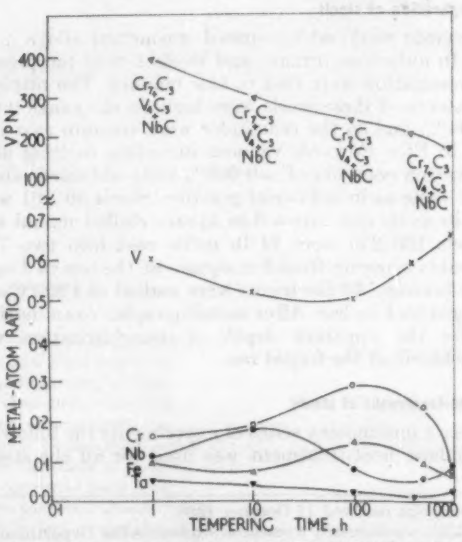
Previous workers[1,2] have employed austenitizing treatments of 4 h at 1200°C followed by an oil quench for 0·2%C–Cr–V(–Mo) steels. When this heat-treatment was employed in the present investigation, NbC was identified in the as-quenched state. The temperature might have been too low to effect a complete solution of the niobium carbide or precipitation might have occurred during the quench. More vigorous quenches into water and 5% iced brine were no more effective and therefore the following solution treatments were tried for steels 1 and 2:

(i) 4 h at 1300°C
(ii) 4 h at 1350°C
(iii) 4 h at 1400°C
(iv) 4 h at 1400°C followed by ½ h at 1150°C to prevent δ ferrite formation
(v) 24 h at 1300°C.

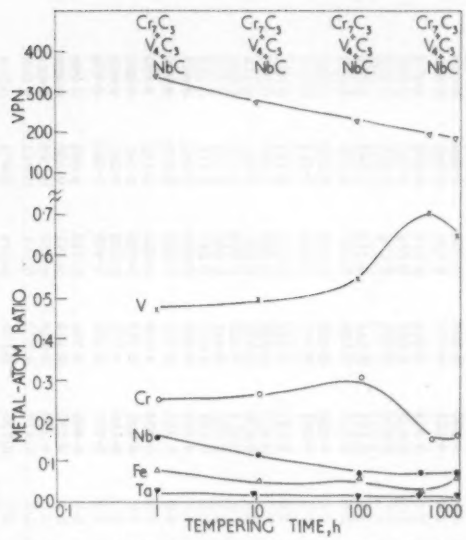
All these heat-treatments were followed by a very efficient quench into iced 9% brine, but none succeeded in effecting a complete solution of the niobium carbide. Four steels containing 0·1%Nb and one steel containing 0·05%Nb were investigated, but after 4 h at 1300°C and a brine quench, these steels too contained NbC. Thus no reasonable heat-treatment brought about a complete solution of the NbC and the presence of NbC in the as-quenched state was accepted; a standard heat-treatment of 4 h at 1300°C followed by



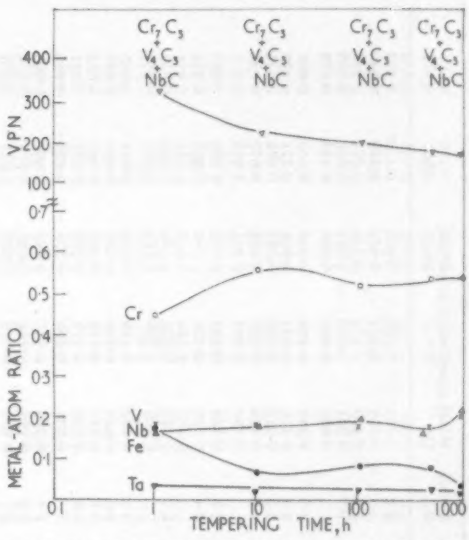
2 *The carbide constitution at 700°C of 0·2%C, 0·2%Nb, Cr–V steels*



4 *The variation in hardness of steel 1 (1·2%Cr, 0·56%V, 0·18%Nb, 0·20%C) and the variation of the metal–atom ratios of the carbide extract with tempering time*



5 *As Fig.4, steel 2 (6·36%Cr, 1·33%V, 0·27%V, 0·20%C)*



7 *As Fig.4, steel 4 (2·0%Cr, 0·25%V, 0·20%Nb, 0·20%C)*

½ h at 1150°C, to prevent δ ferrite formation, was adopted.

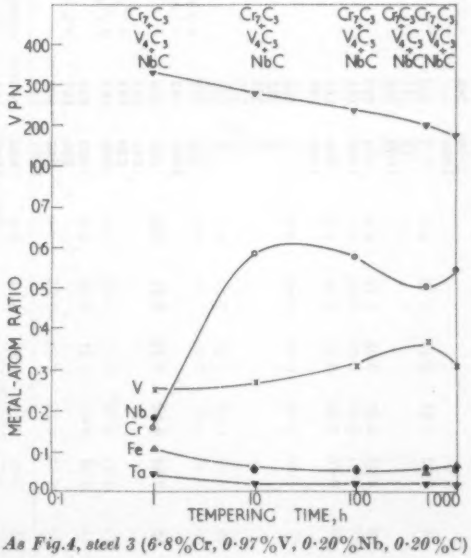
Two 0·2%Nb steels (86 and 88) and several 1·0%Nb steels with high chromium and vanadium contents contained δ ferrite on quenching from 1150°C and it was therefore of interest to examine the relationship of the amount of δ ferrite to the quenching temperature. The amount of δ ferrite remained virtually constant over the range 1050–1150°C and hence little advantage could be gained by lowering the quenching temperature.

The amount of δ ferrite is dependent upon the chromium, vanadium, and niobium contents of the steel (Fig.1). Vanadium and particularly niobium stabilize ferrite, and this is confirmed by the strong dependence of the amount of δ ferrite upon the vanadium and niobium contents. Chromium in amounts from 0–5% acts as an austenite stabilizer and δ ferrite was not observed in this range of composition; in larger amounts it is a ferrite stabilizer.

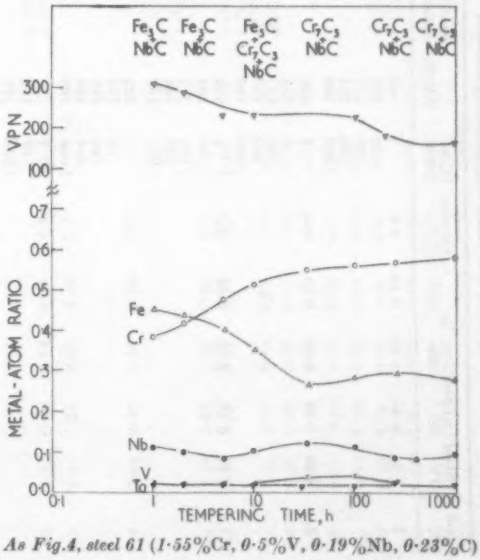
The amount of ferrite was calculated from the chemical composition of the steel using the method suggested by Andrews.[6] In most cases the calculated values were not in good agreement with the observed values, and this is probably because niobium and vanadium are strong carbide formers.

Nature and structure of the carbide phases observed

The carbides observed in this investigation are listed



6 *As Fig.4, steel 3 (6·8%Cr, 0·97%V, 0·20%Nb, 0·20%C)*



8 *As Fig.4, steel 61 (1·55%Cr, 0·5%V, 0·19%Nb, 0·23%C)*

TABLE I Details of experimental steels and extracted carbides

Steel no.	Steel composition, % Cr	V	Nb	C	Ferrite, %	H, at 700°C	V.D.N.	Lattice parameters of carbide in Å	Carbide phases present	Yield, %	Metal-atom ratios in carbide Cr	V	Fe	Nb	Ta
1	1·21	0·56	0·20	0·20	0·0	1	388		V_4C_3+NbC	2·2	0·165	0·600	0·096	0·115	0·064
						10	285		V_4C_3+NbC+Cr_7C_3	...	0·191	0·512	0·070	0·182	0·045
						100	235		V_4C_3+NbC+Cr_7C_3	1·6	0·291	0·478	0·142	0·073	0·021
						500	204		V_4C_3+NbC+Cr_7C_3	1·5	0·241	0·620	0·091	0·040	0·010
						1000	160		V_4C_3+NbC+Cr_7C_3	...	0·070	0·695	0·059	0·126	0·026
2	6·36	1·33	0·20	0·20	0·0	1	339		V_4C_3+NbC+Cr_7C_3	3·2	0·255	0·474	0·079	0·160	0·031
						10	274		V_4C_3+NbC+Cr_7C_3	2·4	0·270	0·531	0·046	0·121	0·032
						100	227	NbC, a= 4·161	V_4C_3+NbC+Cr_7C_3	3·9	0·310	0·550	0·061	0·074	0·015
						500	197	Cr_7C_3, a=14·041	V_4C_3+NbC+Cr_7C_3	2·0	0·165	0·720	0·023	0·072	0·020
						1000	186	c/a= 0·3229	V_4C_3+NbC+Cr_7C_3	...	0·180	0·646	0·071	0·076	0·015
3	6·82	0·97	0·20	0·20	0·0	1	329		NbC+Cr_7C_3	2·6	0·152	0·255	0·110	0·184	0·045
						10	283		NbC+Cr_7C_3	2·4	0·593	0·270	0·066	0·053	0·016
						100	214		V_4C_3+NbC+Cr_7C_3	...	0·583	0·310	0·068	0·054	0·014
						500	194		V_4C_3+NbC+Cr_7C_3	2·7	0·503	0·372	0·058	0·052	0·014
						1000	169		V_4C_3+NbC+Cr_7C_3	...	0·560	0·289	0·090	0·050	0·011
4	2·02	0·25	0·20	0·20	0·0	1	344		NbC+Cr_7C_3	3·3	0·440	0·179	0·171	0·173	0·035
						10	238		NbC+Cr_7C_3	2·2	0·553	0·178	0·185	0·068	0·017
						100	213		NbC+Cr_7C_3+V_4C_3	2·9	0·512	0·176	0·206	0·083	0·022
						500	194		NbC+Cr_7C_3+V_4C_3	1·5	0·536	0·177	0·173	0·079	0·021
						1000	185		NbC+Cr_7C_3+V_4C_3	...	0·535	0·205	0·229	0·028	0·004
5	1·27	0·68	0·12	0·19	0·0	1	...		NbC+V_4C_3+Cr_7C_3	1·7	0·152	0·747	0·040	0·061	0·015
						10	283		NbC+V_4C_3+Cr_7C_3	1·9	0·129	0·764	0·040	0·055	0·014
						1050	194		NbC+V_4C_3+Cr_7C_3	2·1	0·155	0·702	0·082	0·051	0·010
6	6·43	1·50	0·13	0·18	0·0	1	326		NbC+V_4C_3+Cr_7C_3	2·2	0·336	0·571	0·040	0·034	0·018
						10	241		NbC+V_4C_3+Cr_7C_3	1·6	0·153	0·725	0·040	0·051	0·015
						1050	202		NbC+V_4C_3+Cr_7C_3	1·8	0·055	0·735	0·139	0·062	0·008
7	1·97	0·25	0·10	0·19	0·0	1	295		NbC+V_4C_3+Cr_7C_3	1·5	0·440	0·208	0·286	0·056	0·012
						10	262		NbC+V_4C_3+Cr_7C_3	2·1	0·550	0·195	0·205	0·040	0·010
						1050			NbC+V_4C_3+Cr_7C_3	2·2	0·511	0·256	0·180	0·045	0·009
8	7·03	1·07	0·11	0·20	0·0	1	326		NbC+V_4C_3+Cr_7C_3	2·4	0·604	0·278	0·074	0·029	0·014
						10	241		NbC+V_4C_3+Cr_7C_3	2·6	0·643	0·264	0·064	0·025	0·007
						1050	202		NbC+V_4C_3+Cr_7C_3	2·1	0·550	0·206	0·180	0·055	0·014
59	0·75	0·33	0·06	0·19	0·0	100	223		Fe_3C+V_4C_3+NbC	...	0·154	0·531	0·218	0·097	0·014
						1050	181		Fe_3C+V_4C_3+NbC	2·0	0·216	0·360	0·332	0·085	0·013
60	0·76	0·20	0·21	0·19	0·0	100	232		Fe_3C+NbC+V_4C_3 (trace)	2·4	0·225	0·182	0·460	0·102	0·028
						1050	150		Fe_3C+NbC+V_4C_3 (trace)	2·7	0·244	0·187	0·444	0·113	0·013
61	1·55	0·05	0·19	0·23	0·0	1	304		Fe_3C+NbC	2·6	0·385	0·024	0·457	0·112	0·021
						2	283		Fe_3C+NbC+Cr_7C_3?	2·7	0·417	0·018	0·442	0·103	0·020
						5	229		Fe_3C+NbC+Cr_7C_3	2·6	0·479	0·017	0·400	0·082	0·019
						10	230		Fe_3C+NbC+Cr_7C_3	2·3	0·514	0·024	0·350	0·104	0·020
						30	192		Cr_7C_3+NbC	2·1	0·555	0·044	0·263	0·125	0·013
						100	230		Cr_7C_3+NbC	1·8	0·564	0·047	0·287	0·116	0·016
						250	177	a (Cr_7C_3) =13·900	Cr_7C_3+NbC	2·6	0·567	0·029	0·298	0·088	0·028
						1000	163	c/a = 0·329	Cr_7C_3+NbC	2·6	0·584	0·025	0·278	0·098	0·026
62	3·62	0·98	0·21	0·21	0·0	100	210		V_4C_3+NbC	1·2	0·075	0·696	0·094	0·112	0·038
						240	193		V_4C_3+NbC	2·0	0·350	0·284	0·174	0·161	0·031
						540	191		Cr_7C_3+V_4C_3+NbC	...	0·114	0·710	0·053	0·106	0·018
						1000	181	a (V_4C_3) = 4·161	Cr_7C_3+V_4C_3+NbC	3·4	0·319	0·525	0·085	0·066	0·005
63	3·54	0·63	0·21	0·19	0·0	100	218		V_4C_3+NbC+Cr_7C_3	1·7	0·409	0·364	0·144	0·065	0·020
						240	197		V_4C_3+NbC+Cr_7C_3	2·1	0·298	0·453	0·121	0·106	0·021
						535	189		V_4C_3+NbC+Cr_7C_3	...	0·378	0·402	0·097	0·117	0·021
						1000	189		V_4C_3+NbC+Cr_7C_3	4·2	0·478	0·373	0·101	0·042	0·006
64	4·00	0·27	0·21	0·19	0·0	100	200	a (Cr_7C_3) =14·075	NbC+V_4C_3+Cr_7C_3 (trace)	2·7	0·705	0·125	0·088	0·073	0·010
						1000	177	c/a = 0·3127	NbC+V_4C_3+Cr_7C_3 (trace)	3·3	0·665	0·182	0·085	0·064	0·008

TABLE I—*Continued* **Details of experimental steels and extracted carbides**

Steel no.	Steel composition, % Cr	V	Nb	C	Ferrite, %	H, at 700°C	V.D.N.	Lattice parameters of carbide in *kx*	Carbide phases present	Yield, %	Metal-atom ratios in carbide Cr	V	Fe	Nb	Ta
68	4·13	0·17	0·23	0·22	0·0	100	203		Cr_7C_3+NbC	2·2	0·728	0·043	0·125	0·084	0·020
						200	178	a (Cr_7C_3) = 13·892	Cr_7C_3+NbC	3·1	0·685	0·148	0·132	0·037	0·006
						1000	187	c/a = 0·3205	Cr_7C_3+NbC	2·8	0·384	0·340	0·129	0·115	0·224
69	6·87	0·55	0·23	0·23	0·0	100	213		Cr_7C_3+NbC	2·1	0·673	0·087	0·125	0·093	0·022
						200	188	a (Cr_7C_3) = 13·996	Cr_7C_3+NbC	2·3	0·698	0·077	0·117	0·091	0·017
						1000	172	c/a = 0·3207	Cr_7C_3+NbC	4·3	0·677	0·153	0·126	0·047	0·006
70	6·41	1·55	0·22	0·22	n.d.*	100	225	a (V_4C_3) = 4·150	V_4C_3+NbC	1·5	0·077	0·706	0·034	0·143	0·043
						1000	171	a (NbC) = 4·420	V_4C_3+NbC	1·5	0·069	0·724	0·035	0·145	0·029
83	0·79	0·33	0·18	0·22	0·0	1060	186		NbC+V_4C_3	...	0·119	0·568	0·112	0·171	0·031
84	8·01	0·85	0·22	0·24	0·0	0·75	353		Cr_7C_3+NbC	3·4	0·589	0·147	0·157	0·093	0·008
						4·3	264		Cr_7C_3+NbC	2·9	0·652	0·133	0·119	0·089	0·008
						10	232		Cr_7C_3+NbC	2·5	0·699	0·180	0·055	0·056	0·011
						30	221		Cr_7C_3+NbC+($Cr_{23}C_6$?)	2·5	0·690	0·190	0·064	0·057	0·046
						100	218		Cr_7C_3+NbC+$Cr_{23}C_6$ (trace)	2·9	0·745	0·137	0·056	0·055	0·009
						210	206		Cr_7C_3+NbC+$Cr_{23}C_6$ (trace)	2·4	0·747	0·134	0·058	0·053	0·015
						400	201		Cr_7C_3+$Cr_{23}C_6$+NbC	4·2	0·727	0·131	0·069	0·065	0·008
						1060	191		Cr_7C_3+$Cr_{23}C_6$+NbC	2·9	0·610	0·202	0·136	0·043	0·008
85	9·11	0·88	0·20	0·22	0·0	0·75	346		Cr_7C_3+NbC	2·9	0·682	0·120	0·113	0·071	0·015
						3	281		Cr_7C_3+NbC	2·9	0·672	0·168	0·082	0·064	0·014
						10	237		Cr_7C_3+NbC	2·8	0·732	0·166	0·058	0·044	0·033
						30	221		Cr_7C_3+NbC	2·6	0·710	0·161	0·071	0·052	0·006
						100	218		Cr_7C_3+$Cr_{23}C_6$+NbC	3·2	0·720	0·102	0·074	0·086	0·018
						210	194		Cr_7C_3 (trace)+$Cr_{23}C_6$+NbC	3·5	0·743	0·125	0·097	0·030	0·005
						400	201		$Cr_{23}C_6$+NbC	3·5	0·727	0·131	0·069	0·065	0·008
						1060	187	a ($Cr_{23}C_6$) = 10·633	$Cr_{23}C_6$+NbC	4·1	0·695	0·155	0·113	0·027	0·009
86	9·11	1·07	0·20	0·24	0·8	0·75	348		Cr_7C_3+NbC+V_4C_3 (faint)	3·5	0·610	0·176	0·128	0·070	0·015
						3	292		Cr_7C_3+NbC+V_4C_3 (faint)	2·9	0·550	0·315	0·082	0·055	0·011
						10	236		Cr_7C_3+NbC+V_4C_3	2·5	0·623	0·254	0·048	0·066	0·015
						30	229		Cr_7C_3+NbC+V_4C_3	2·6	0·690	0·186	0·062	0·057	0·006
						100	219		Cr_7C_3+V_4C_3+NbC+$Cr_{23}C_6$ (trace)	2·5	0·700	0·156	0·086	0·045	0·019
						212	199		Cr_7C_3+NbC+$Cr_{23}C_6$+V_4C_3	2·8	0·717	0·144	0·073	0·051	0·015
						400	195	a (NbC) = 4·432	Cr_7C_3+NbC+$Cr_{23}C_6$+V_4C_3	2·8	0·598	0·234	0·104	0·060	0·013
						1000	169	a ($Cr_{23}C_6$) = 10·638	$Cr_{23}C_6$+NbC+V_4C_3	3·0	0·637	0·215	0·106	0·039	0·004
88	7·32	1·50	0·21	0·24	6·3	0·75	360		Cr_7C_3+NbC+V_4C_3?	3·4	0·392	0·434	0·074	0·083	0·017
						4·3	285		Cr_7C_3+NbC+V_4C_3	2·4	0·442	0·418	0·050	0·082	0·017
						10	224		Cr_7C_3+NbC+V_4C_3	2·2	0·290	0·567	0·063	0·074	0·005
						30	214		Cr_7C_3+NbC+V_4C_3	2·0	0·190	0·694	0·027	0·088	0·006
						100	200		$Cr_{23}C_6$+Cr_7C_3+V_4C_3+NbC	...	0·185	0·716	0·020	0·065	0·013
						212	206	a (NbC) = 4·427	$Cr_{23}C_6$+Cr_7C_3+V_4C_3+NbC	2·0	0·250	0·661	0·031	0·043	0·015
						400	198	a (V_4C_3) = 4·172	$Cr_{23}C_6$+Cr_7C_3+V_4C_3+NbC	2·1	0·232	0·660	0·029	0·065	0·014
						1000	170	a ($Cr_{23}C_6$) = 10·62	$Cr_{23}C_6$+NbC+V_4C_3	2·3	0·170	0·685	0·033	0·094	0·013
89	7·49	0·64	0·20	0·24	0·0	1060	174		Cr_7C_3+$Cr_{23}C_6$ (trace)+NbC	2·4	0·669	0·208	0·063	0·050	0·013
90	6·55	1·52	0·24	0·23	n.d.*	1060	191	a (NbC) = 4·425 a (V_4C_3) = 4·164	V_4C_3+NbC	2·4	0·121	0·764	0·046	0·066	0·004
91	3·52	0·80	0·20	0·22	0·0	1060	203		Cr_7C_3+V_4C_3+NbC	3·1	0·406	0·408	0·125	0·049	0·012
96	1·23	0·49	0·20	0·19	0·0	1000	168		V_4C_3+NbC+Cr_7C_3	2·2	0·324	0·409	0·195	0·066	0·005
97	0·72	0·45	0·23	0·21	0·0	1000	168		V_4C_3+NbC	1·3	0·048	0·634	0·081	0·190	0·010
98	0·71	0·57	0·17	0·22	0·0	1000	169		V_4C_3+NbC	1·3	0·046	0·715	0·074	0·152	0·015
99	0·72	0·76	0·34	0·21	0·0	1000	153		V_4C_3+NbC+VC?	2·0	0·027	0·775	0·083	0·114	0·010
100	3·39	1·12	0·20	0·19	0·0	1000	174	a (NbC) = 4·447 a (V_4C_3) = 4·158	V_4C_3+NbC	2·3	0·052	0·780	0·063	0·098	0·007
101	1·18	1·0	0·21	0·19	0·0	1000	167		Cr_7C_3+V_4C_3+NbC	2·0	0·297	0·570	0·042	0·074	0·010
130	0·0	0·4	0·90	0·20	n.d.*	300	212	a (NbC) = 4·458	V_4C_3+NbC	2·2	...	0·418	0·065	0·467	0·051
						1000	174	a (V_4C_3) = 4·735	V_4C_3+NbC	2·0		0·408	0·032	0·505	0·053
						680°C 1000 h	170		V_4C_3+NbC+X	2·0	...	0·318	0·073	0·571	0·039

*n.d. = not determined

TABLE I—*Continued* **Details of experimental steels and extracted carbides**

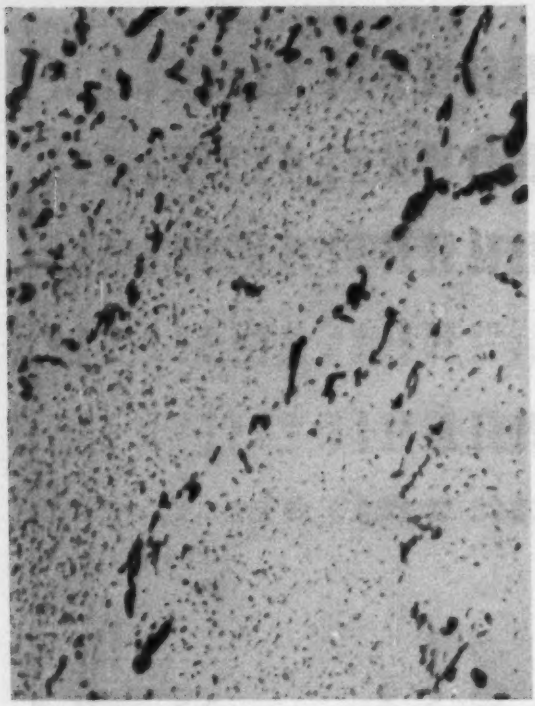
Steel no.	Steel composition, % Cr	V	Nb	C	Ferrite, %	H, at 700°C	V.D.N.	Lattice parameters of carbide in *kx*	Carbide phases present	Yield, %	Metal–atom ratios in carbide Cr	V	Fe	Nb	Ta
131	0·0	0·63	0·91	0·19	n.d.*	300	202	a (NbC) = 4·452	NbC+V_4C_3	2·3	...	0·523	0·053	0·405	0·020
						1000		a (V_4C_3) = 4·170	NbC+V_4C_3	1·6	...	0·475	0·026	0·470	0·033
						680°C 1000 h			NbC+V_4C_3	1·6	...	0·424	0·037	0·507	0·035
132	0·0	0·0	0·93	0·21	0·0	300	128		NbC only	1·5	...	...	0·120	0·840	0·039
						1000	121	a (NbC) = 4·460	NbC only	1·3	...	...	0·057	0·873	0·073
						680°C 1000 h			NbC only	1·6	...	...	0·075	0·865	0·060
134	0·0	1·34	0·97	0·21	11·5	300	191	a (NbC) = 4·447	NbC+V_4C_3 (trace)	2·1	...	0·454	0·019	0·516	0·012
						1000	178	a (V_4C_3) = 4·169	NbC+V_4C_3	2·2	...	0·500	0·013	0·445	0·044
135	0·0	1·95	1·05	0·21	n.d.*	300	172	a (NbC) = 4·4385	NbC+V_4C_3	1·8	...	0·405	0·023	0·530	0·043
						1000	166	a (V_4C_3) = 4·163	NbC+V_4C_3	2·1	...	0·463	0·012	0·474	0·047
						680°C 1000 h	142		NbC+V_4C_3	1·8	...	0·352	0·054	0·569	0·041
136	0·0	0·14	0·90	0·23	0·0	300	168		NbC+V_4C_3 (trace)	2·0	...	0·145	0·121	0·681	0·052
						1000	113	a (NbC) = 4·4585	NbC+V_4C_3	1·6	...	0·140	0·086	0·713	0·060
						680°C 1000 h			NbC+V_4C_3+X	1·9	...	0·159	0·060	0·730	0·053
137	0·48	...	0·92	0·22	0·0	312	175		Fe_3C+NbC	2·3	0·124	...	0·302	0·550	0·024
						1000	122	a (NbC) = 4·459	NbC+Fe_3C?	1·4	0·014	...	0·077	0·805	0·104
						680°C 1000 h			Fe_3C+NbC	1·8	0·050	...	0·181	0·720	0·048
138	2·55	...	0·91	0·22	0·0	300	163?	a (NbC) = 4·457	NbC+Cr_7C_3	2·8	0·501	...	0·132	0·340	0·026
						1000	164	a (Cr_7C_3) = 13·960 c/a = 0·322	NbC+Cr_7C_3	2·5	0·525	...	0·109	0·358	0·011
139	6·26	...	0·97	0·19	0·0	300	179	a (NbC) = 4·458	NbC+Cr_7C_3	2·4	0·527	...	0·044	0·394	0·037
						1000	145	a (Cr_7C_3) = 13·990 c/a = 0·325	NbC+Cr_7C_3+$Cr_{23}C_6$ (trace)	2·5	0·620	...	0·056	0·309	0·015
141	9·00	...	0·94	0·22	0·0	300	188	a (NbC) = 4·454	NbC+$Cr_{23}C_6$	3·6	0·665	...	0·095	0·232	0·009
						1000	164	a ($Cr_{23}C_6$) = 10·588	NbC+$Cr_{23}C_6$	3·2	0·615	...	0·101	0·277	0·007
143	7·3	...	0·96	0·19	0·0	1			NbC+Cr_7C_3	2·3	0·473	...	0·069	0·455	0·026
						30			NbC		0·552	...	0·110	0·316	0·021
						100	161		NbC+$Cr_{23}C_6$	2·0					
						300	175	a (NbC) = 4·458	NbC+$Cr_{23}C_6$	2·8	0·560	...	0·089	0·341	0·010
						1000	150	a ($Cr_{23}C_6$) = 10·596	NbC+$Cr_{23}C_6$	2·7	0·615	...	0·101	0·277	0·007
144	11·3	...	0·91	0·19	16·2	300	187	a (NbC) = 4·454	NbC+$Cr_{23}C_6$	2·5	0·595	...	0·064	0·324	0·017
						1000	150	a ($Cr_{23}C_6$) = 10·607	NbC+$Cr_{23}C_6$	2·5	0·551	...	0·076	0·359	0·016
177	...	0·08	1·10	0·19	0·0	1000			NbC+V_4C_3?		...	0·049	0·093	0·805	0·053
178	0·49	0·10	1·05	0·18	0·0	1000	130		NbC+V_4C_3+X	2·1	0·0	0·084	0·073	0·796	0·048
179	1·98	0·03	1·14	0·21	0·0	0·17	294		NbC+Fe_3C?	2·8	0·156	0·022	0·249	0·534	0·041
						1	226		NbC+Cr_7C_3	2·0	0·294	0·009	0·157	0·492	0·047
						3	214		NbC+Cr_7C_3	2·6	0·330	0·009	0·136	0·493	0·033
						10	200		NbC+Cr_7C_3	2·3	0·270	0·010	0·110	0·580	0·032
						99	184		NbC+Cr_7C_3	2·0	0·230	0·022	0·097	0·618	0·028
						300	135		NbC+Cr_7C_3	2·8	0·289	0·009	0·114	0·556	0·031
						1000	160		NbC+Cr_7C_3	2·0	0·310	0·004	0·105	0·547	0·034
180	2·07	0·21	1·12	0·20	0·0	1000	169		NbC+V_4C_3+Cr_7C_3	2·5	0·244	0·123	0·084	0·466	0·034
181	0·95	0·34	1·13	0·18	0·0	1000	124		NbC+V_4C_3	1·8	0·000	0·183	0·053	0·715	0·048
182	4·45	0·23	1·03	0·20	0·0	1000	141		Cr_7C_3+NbC	2·0	0·349	0·021	0·090	0·494	0·047
185	4·84	1·15	1·02	0·19	0·4	1000	161		NbC+V_4C_3	1·8	0·003	0·303	0·026	0·653	0·015
186	6·55	1·26	1·15	0·19	21·8	1000	138		NbC+V_4C_3	1·5	0·021	0·109	0·030	0·795	0·043

*n.d. = not determined

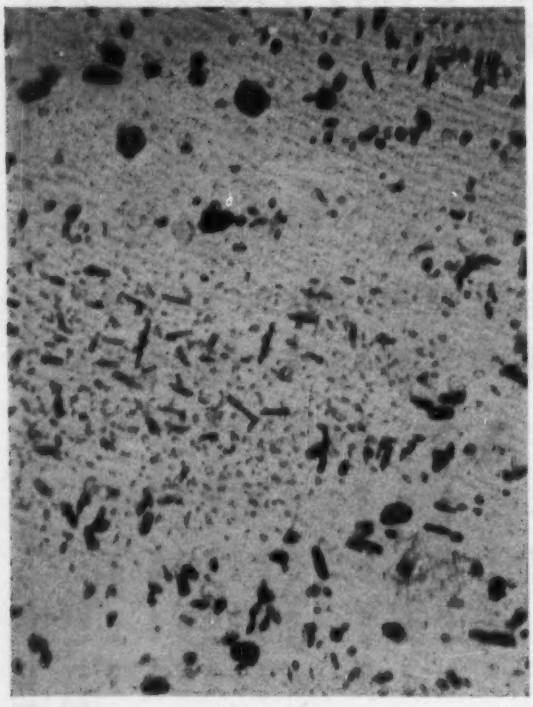
TABLE I—*Continued* **Details of experimental steels and extracted carbides**

Steel no.	Steel composition, % Cr	V	Nb	C	Ferrite, %	H, at 700°C	V.D.N.	Lattice parameters of carbide in Å	Carbide phases present	Yield, %	Metal-atom ratios in carbide Cr	V	Fe	Nb	Ta
187	8·45	1·08	1·15	0·21	17·5	1			NbC+Cr_7C_3+$Cr_{23}C_6$	3·0	0·056	0·018	0·242	0·656	0·045
						3	227		NbC+Cr_7C_3+$Cr_{23}C_6$	2·4	0·384	0·052	0·058	0·469	0·037
						11·3	207		NbC+Cr_7C_3+$Cr_{23}C_6$	2·4	0·437	0·018	0·072	0·413	0·027
						24	168		NbC+Cr_7C_3+$Cr_{23}C_6$						
						99	184		NbC+$Cr_{23}C_6$	2·8	0·442	0·036	0·082	0·407	0·029
						300	161		NbC+$Cr_{23}C_6$	2·6	0·420	0·038	0·060	0·450	0·034
						1000	166		NbC+$Cr_{23}C_6$	1·9	0·448	0·035	0·084	0·415	0·019
188	8·15	2·70	0·99	0·20	92·0	1000	156		NbC+V_4C_3	2·2	0·023	0·326	0·028	0·600	0·022
189	8·00	1·46	0·93	0·20	47·0	1	232		NbC+Cr_7C_3	2·4	0·170	0·218	0·045	0·532	0·035
						3	198		NbC	2·0	0·108	0·150	0·062	0·634	0·046
						11·3	191		NbC+Cr_7C_3	2·1	0·199	0·295	0·031	0·483	0·031
						100	174		NbC+$Cr_{23}C_6$+V_4C_3	3·1	0·149	0·310	0·029	0·498	0·025
						300	158		NbC+$Cr_{23}C_6$+V_4C_3	2·8	0·126	0·240	0·070	0·528	0·036
						1000	140		NbC+$Cr_{23}C_6$+V_4C_3	2·1	0·106	0·318	0·036	0·516	0·024
190	7·95	2·01	0·91	0·19	74·2	1000	145		NbC+V_4C_3	2·0	0·009	0·189	0·063	0·720	0·017
199	1·28	0·58	0·95	0·18	0·0	1000	158		NbC+V_4C_3	1·8	0·000	0·234	0·032	0·690	0·044
200	6·15	...	0·23	0·20	0·0	1000	169		NbC+Cr_7C_3	2·5	0·815	...	0·101	0·080	0·007
201	6·60	...	0·19	0·19	0·0	1000	176	a (NbC) = 4·459 a ($Cr_{23}C_6$) = 10·592	NbC+Cr_7C_3+$Cr_{23}C_6$	3·0	0·780	...	0·140	0·076	0·006
202	6·25	...	1·65	0·20	0·0	460	161		NbC+$Cr_{23}C_6$+(Cr_7C_3?)	2·5	0·061	...	0·043	0·844	0·055
						1000	174		NbC+$Cr_{23}C_6$+(Cr_7C_3?)	3·2	0·009	...	0·067	0·865	0·042
203	6·74	...	1·62	0·19	0·0	460	164		NbC+$Cr_{23}C_6$	2·7	0·129	...	0·048	0·773	0·050
						1000	170		NbC+$Cr_{23}C_6$	2·6	0·009	...	0·095	0·855	0·047
204	6·40	0·93	0·98	0·21	5·0	460	167		NbC+V_4C_3+Cr_7C_3	2·2	0·109	0·172	0·062	0·613	0·045
						1000	171		NbC+V_4C_3+Cr_7C_3+$Cr_{23}C_6$	2·5	0·288	0·084	0·056	0·547	0·025
205	6·37	1·18	0·98	0·19	17·3	460	165		NbC+V_4C_3	1·8	0·067	0·256	0·073	0·567	0·039
						1000	183		NbC+V_4C_3+$Cr_{23}C_6$ (trace)	2·3	0·068	0·280	0·056	0·535	0·032
206	6·85	0·77	0·98	0·21	3·0	460	168		NbC+Cr_7C_3	2·1	0·303	0·102	0·014	0·545	0·036
						1000	172		NbC+Cr_7C_3+$Cr_{23}C_6$	2·8	0·433	0·068	0·095	0·380	0·021
208	6·95	0·76	0·97	0·20	1·8	1000	167		NbC+$Cr_{23}C_6$	3·2	0·460	0·103	0·058	0·377	0·023
209	7·54	...	0·25	0·17	0·0	1000	165	a ($Cr_{23}C_6$) = 10·597 a (NbC) = 4·459	NbC+$Cr_{23}C_6$	3·8	0·732	...	0·155	0·107	0·008
222	4·56	0·50	0·93	0·17	0·2	1000	177		NbC+Cr_7C_3+X	1·7	0·192	0·069	0·021	0·538	0·035
223	7·05	0·96	0·85	0·17	21·5	1000	177		NbC+$Cr_{23}C_6$	2·3	0·388	0·082	0·076	0·427	0·025
224	7·30	0·93	0·83	0·17	13·8	1000	169		NbC+$Cr_{23}C_6$	2·0	0·391	0·082	0·075	0·425	0·028
225	7·50	1·35	0·95	0·18	45·5	1000	167		NbC+V_4C_3+$Cr_{23}C_6$	2·4	0·202	0·215	0·040	0·510	0·033
226	7·45	1·47	0·96	0·17	47·5	1000	167		NbC+V_4C_3+$Cr_{23}C_6$	2·2	0·183	0·248	0·049	0·476	0·042
227	5·60	0·68	0·87	0·18	0·0	1000	168	a (NbC) = 4·454 a (Cr_7C_3) = 13·969	NbC+Cr_7C_3+X	2·6	0·423	0·091	0·082	0·384	0·023
228	5·56	0·94	0·87	0·17	18·0	1000	168		NbC+V_4C_3+Cr_7C_3	2·4	0·112	0·298	0·066	0·495	0·028
229	4·64	0·83	0·94	0·13	n.d.*	1000	177		NbC+V_4C_3+Cr_7C_3 (trace)	1·6	0·010	0·164	0·010	0·800	0·027
230	...	...	0·23	0·24	n.d.*	1000	129		NbC+Fe_3C?	1·0	...	...	0·230	0·740	0·038

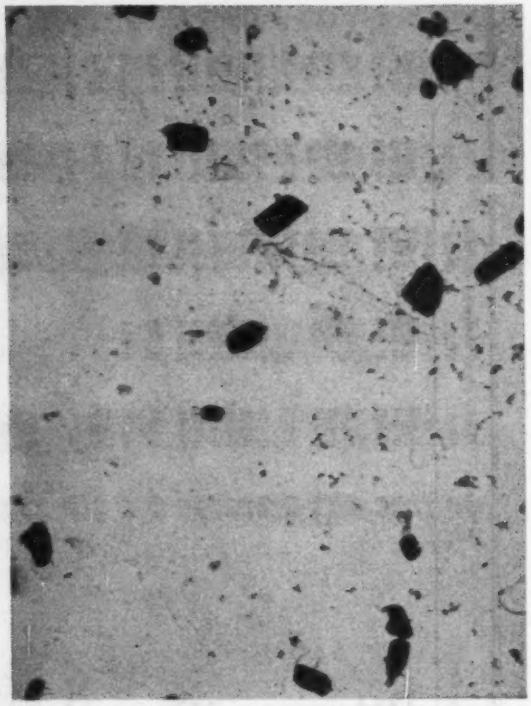
* n.d. = not determined



9 *Electron micrograph of steel 61 tempered for 1 h at 700°C. Carbon extraction replica* ×9000



10 *Electron micrograph of steel 61 tempered for 10 h at 700°C. Carbon extraction replica* ×9000



11 *Electron micrograph of steel 61 tempered for 100 h at 700°C. Carbon extraction replica* ×9000

below together with the structures quoted by Goldschmidt[7]:

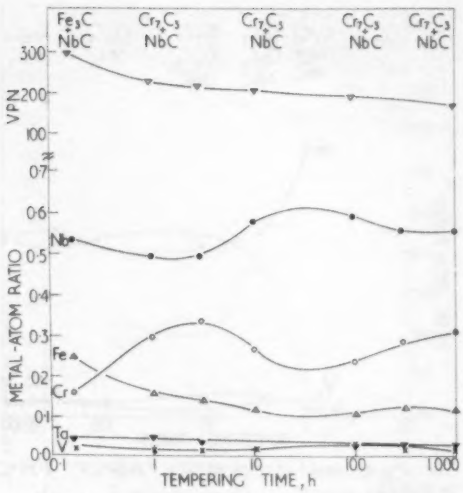
Fe_3C	orthorhombic with 16 atoms/unit cell
Cr_7C_3	hexagonal with 80 atoms/unit cell
$Cr_{23}C_6$	complex cubic with 116 atoms/unit cell
VC–V_4C_3	NaCl-structure a=4·30–4·13 kx
NbC–Nb_4C_3	NaCl-structure a=4·46–4·42 kx.

In addition another phase, denoted x in Table I, was observed; the d values which are given in Table II do not correspond to any known carbide or intermetallic phase but give a reasonable agreement with (FeMn)O $(NbTa)_2O_5$.

TABLE II Comparison of the d values of the phase X with the d values of the phase $(FeMn)O.(NbTa)_2O_5$

d values for phase X observed in the various steels					
Steel no.130 as-quenched	Steel no.203 as-quenched	Steel no.130 tempered	Steel no.227 tempered	Steel no.222 tempered	$(FeMn)O.(NbTa)_2O_5$
3·34	3·34				3·34 (ms)
2·84	...	2·85	2·85	2·85 (s)	2·86
2·72	...	2·76	2·75	2·76 (s)	...
2·54	2·54	2·54	2·60	2·58	2·58 (ms)
2·29					2·37
2·26	2·28	2·28	2·28	2·26	2·26
2·14		2·12	2·15		2·11
					1·94
					1·86
	1·73				1·75 (s)
1·65			1·66	1·65	1·68
					1·55
					1·50
			1·45	1·43	1·43
					1·40
1·29					1·30

ms = medium strong s = strong

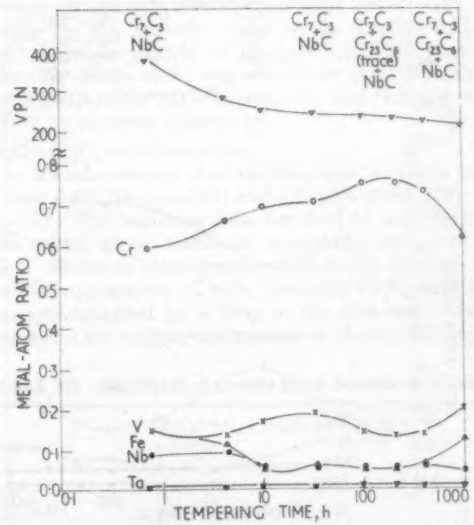


12 *As Fig.4, steel 179 (1·98%Cr, 0·03%V, 1·14%Nb, 0·21%C)*

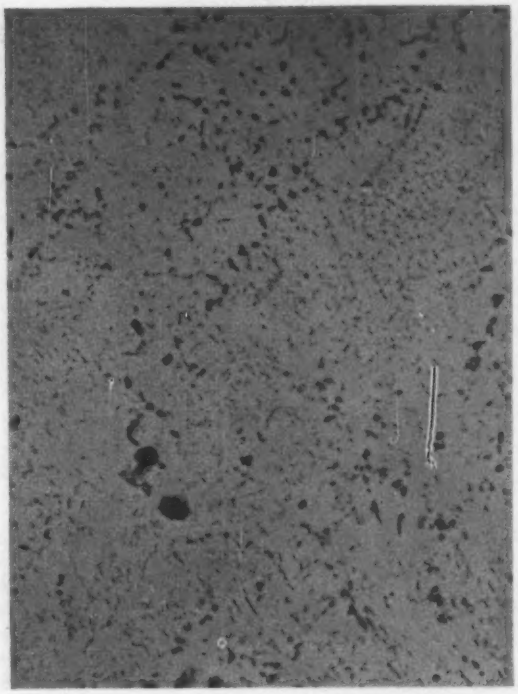
The presence of this compound in vacuum-melted alloys is surprising but could result from oxide impurities in the ferroniobium; an alternative, more likely explanation is that fine carbide particles are oxidized during extraction. The discrepancies between d values observed and those for (FeMn)O $(NbTa)_2O_5$ could be caused by the solubility of the other alloying elements in this compound.

Niobium carbide has a range of existence from NbC to Nb_4C_3 and the lattice parameter varies from 4·457 *kx* to 4·420 *kx*. The observed parameter for niobium carbide in 1·0%Nb, 0·2%C steel (steel 132) was 4·460 *kx* and this suggests the formula NbC.

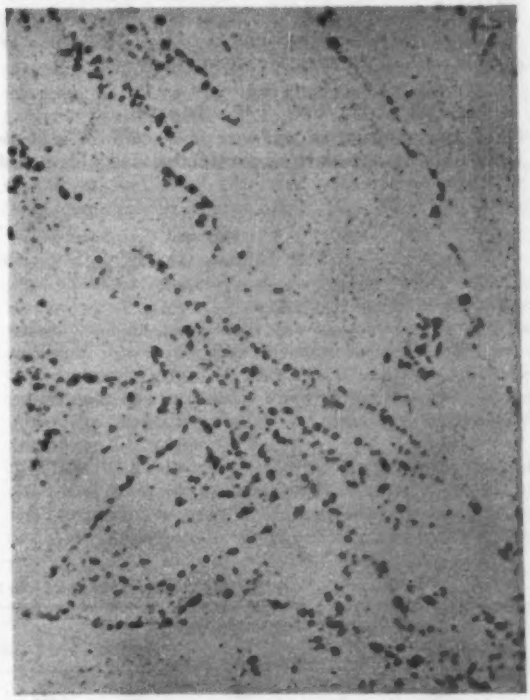
Vanadium carbide is also known to exist over the composition range VC–V_4C_3 and Schonberg[8] reports lattice parameters of 4·183 *kx* and 4·136 *kx* for VC and



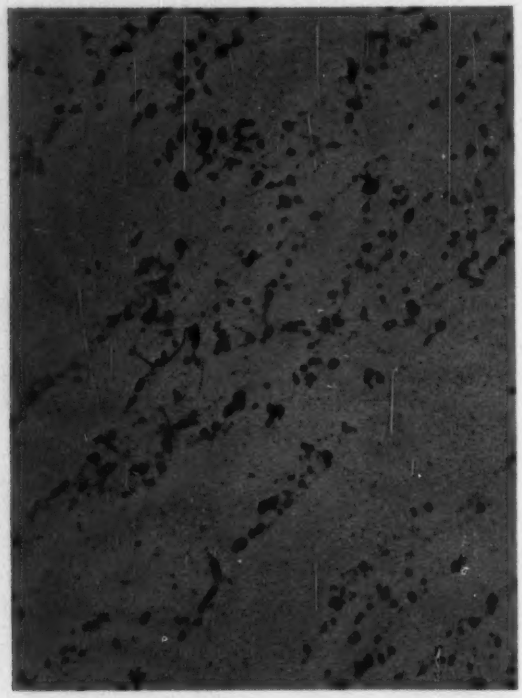
13 *As Fig.4, steel 84 (8·01%Cr, 0·88%V, 0·20%Nb, 0·24%C)*



14 *Electron micrograph of steel 84 tempered for 1 h at 700°C. Carbon extraction replica* ×12000



15 *Electron micrograph of steel 84 tempered for 4 h at 700°C. Carbon extraction replica* ×12000

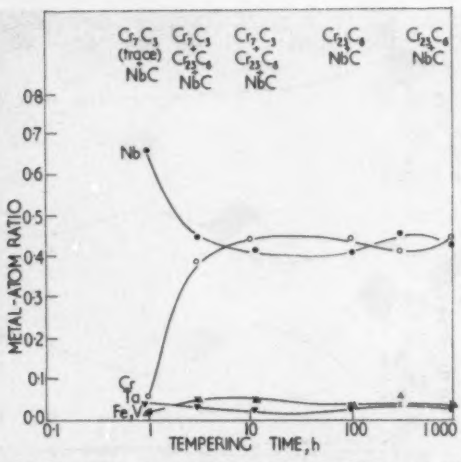


16 *Electron micrograph of steel 84 tempered for 1000 h at 700°C. Carbon extraction replica* ×12000

V_4C_3 respectively. Shaw and Quarrell[1] found a variation between 4·137 and 4·151 *kx* and suggested that vanadium carbide approximated to V_4C_3 in steels. The atomic radii of the metallic elements present are:

Ta	Nb	V	Cr	Fe	
1·65	1·63	1·52	1·42	1·40	(*kx* units)

Thus any solution of niobium in vanadium carbide would increase its lattice parameter, and this could account for the slightly higher lattice parameters (4·15–4·17 *kx*) observed in this investigation.

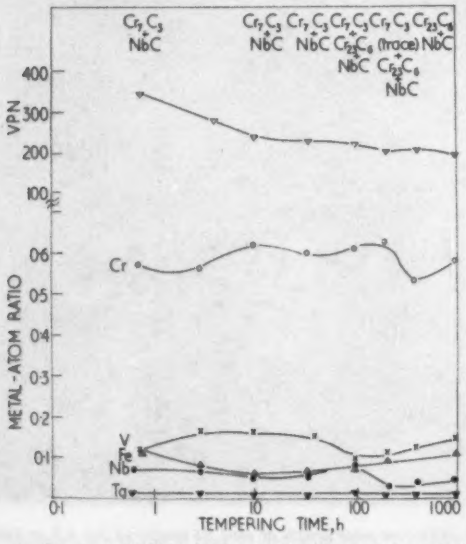


18 *As Fig.4, steel 187 (8·45%Cr, 1·08%V, 1·15%Nb, 0·21%C)*

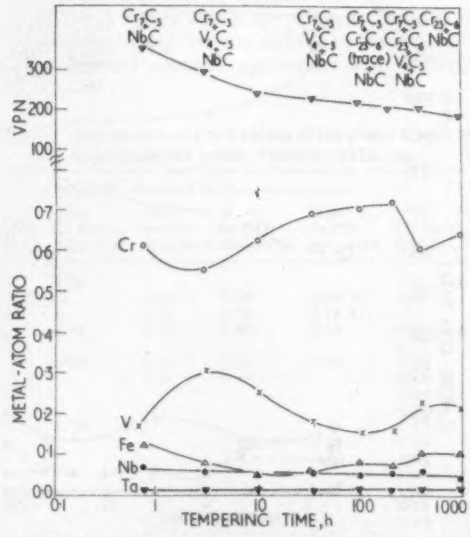
The carbides NbC and V_4C_3 were only partly mutually soluble in the steels and this confirms Krainer's work.[14] The lattice parameters of V_4C_3 were almost independent of the niobium content but the lattice parameters of NbC varied from 4·460 in the absence of vanadium to 4·440 in the presence of 1·95%V. In chromium steels the lattice parameter of NbC was almost independent of the chromium content.

Carbide constitution at 700°C

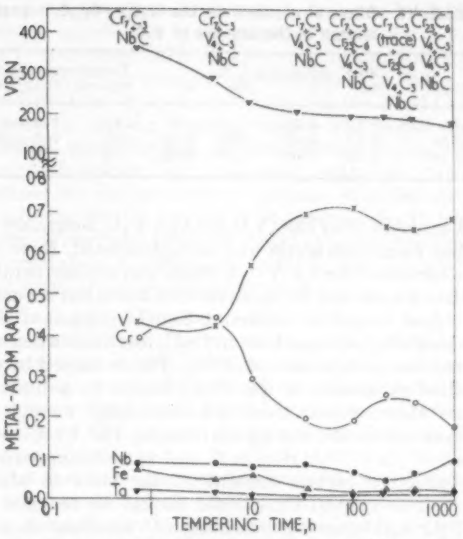
The carbide phases observed in 0·2%C–Cr–V steels containing 0·2% and 1·0%Nb after 1000 h tempering are given in Figs.2 and 3 respectively; the dotted lines represent the carbide phase boundaries determined by Shaw and Quarrell[1] for niobium-free steels. Details of the chemical compositions of the steels and carbide extracts are given in Table I.



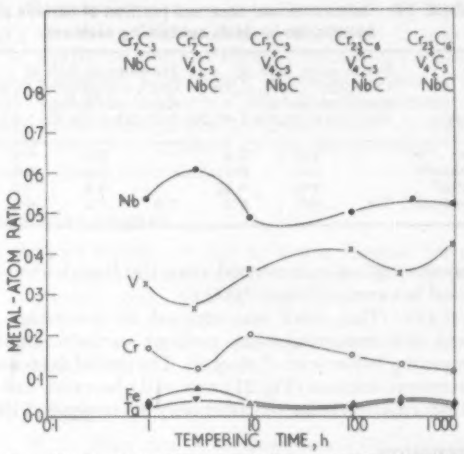
17 *As Fig.4, steel 85 (9·11%Cr, 0·88%V, 0·20%Nb, 0·24%C)*



19 *As Fig.4, steel 86 (9·11%Cr, 1·07%V, 0·20%Nb, 0·24%C)*



20 *As Fig.4, steel 88 (7·32%Cr, 1·52%V, 0·21%Nb, 0·24%C)*



21 *As Fig.4, steel 189 (8·00%Cr, 1·46%V, 0·93%Nb, 0·20%C)*

Investigation of the tempering process at 700°C

The approach to equilibrium of several 0·2%C–Cr–V–Nb steels was followed by chemical and X-ray analysis and the morphology of the carbides was studied by electron microscopy. When the presence of δ ferrite resulted in a non-uniform distribution of the carbides the process was not studied in detail.

The steels investigated were selected to typify the following tempering processes:

(i) no carbide transformation occurs (steels 1–4)
(ii) the $Fe_3C \rightarrow Cr_7C_3$ transformation (steels 61 and 178)
(iii) the $Cr_7C_3 \rightarrow Cr_{23}C_6$ transformation (steels 84, 85, and 187)
(iv) the $Cr_7C_3 \rightarrow Cr_{23}C_6$ transformation in the presence of V_4C_3 (steels 86, 88, and 189).

The hardness values for steels 1–4 shown in Figs.4–7 indicate a smooth relationship with time, with no change in the carbide constitution ($Cr_7C_3 + V_4C_3 +$ NbC), and very little in composition. The gradual softening of the steels was caused by spheroidization and growth of the carbide particles, and this was confirmed by electron microscopy.

$Fe_3C \rightarrow Cr_7C_3$ *transformation*

This transformation was investigated in steels containing 0·2%Nb (steel 61) and 1·0%Nb (steel 179).

Steel 61 The hardness data for steel 61 and the carbide metal–atom ratios on tempering are given in Fig.8. Electron micrographs (Figs.9–11) showed the gradual appearance of rods, probably Cr_7C_3, and this was accompanied by a drop in the iron metal–atom ratios and a simultaneous increase in chromium metal–atom ratio. Further tempering resulted in the growth of the carbide particles.

Steel 179 In this steel the transformation occurred at a much earlier stage of the tempering process and was completed after tempering for 1 h at 700°C (Fig.12).

$Cr_7C_3 \rightarrow Cr_{23}C_6$ *transformation*

Steel 84 The transformation, which occurred after 100 h, was accompanied by a drop in the chromium metal–atom ratios (Fig.13) a fact previously observed.[1] Figures 14–16 illustrate changes in microstructure on tempering. A fine needle-like precipitate was observed during the early stages but this disappeared on further tempering, leaving large grain boundary carbides.

Steel 85 The changes in hardness and metal–atom ratios on tempering (Fig.17) are very similar to those for steel 84. However, the final size of the carbide particles is much greater.

Steel 187 This steel was studied to investigate the effect of increased Nb content on the $Cr_7C_3 \rightarrow Cr_{23}C_6$ transformation. The principal effect was that the transformation occurred after only 3 h tempering (Fig.18).

$Cr_7C_3 \rightarrow Cr_{23}C_6$ *in the presence of* V_4C_3

Steel 86 The transformation occurs after 100 h tempering (Fig.19). An anomalous peak in the vanadium content of the carbide observed after 3 h is probably due to the loss of newly formed $Cr_{23}C_6$ particles during extraction and this is supported by the initial decrease in carbide yield. After this anomalous peak the vanadium content remained reasonably constant.

Steel 88 The tempering behaviour was unlike that of the previous steels as there was an initial decrease in the chromium content of the carbide extract, with a consequent increase in the vanadium content (Fig.20).

TABLE III Movement of carbide phase boundaries for changes of 1%, 0·125%, and 0·025%C

Worker	$Cr_7C_3/Cr_7C_3+Cr_{23}C_6$ shift in %Cr, for −1·0%C	−0·125%C	−0·025%C	$Cr_7C_3+Cr_{23}C_6/Cr_{23}C_6$ Shift in %Cr, for −1·0%C	−0·125%C	−0·025%C
Kuo[9]	−9·0	−0·2	−1·1	−12·5	−0·3	−1·5
Lifshits[10]	−8·0	−0·2	−1·0	−11·0	−0·3	−1·4
Crafts[11]	−4·5	−0·1	−0·55	−7·0	−0·2	−0·85

TABLE IV Calculated and observed position of carbide phase boundaries in steels containing niobium

Worker	Positions in %Cr of $Cr_7C_3/Cr_7C_3+Cr_{23}C_6$ in steels containing 0·0%Nb	0·2%Nb	1·0%Nb	Positions in %Cr of $Cr_7C_3+Cr_{23}C_6/Cr_{23}C_6$ in steels containing 0·0%Nb	0·2%Nb	1·0%Nb
Kuo[9]		6·8	5·9		7·6	6·4
Lifshits[10]		6·8	6·0		7·6	6·5
Crafts[11]		6·9	6·45		7·9	7·0
Observed	7·0	6·7	6·2	7·9	7·5	6·8

Transformation commenced after 100 h and was completed between 400 and 1000 h.

Steel 189 This steel was studied to determine the effect of increased niobium content on the anomalous tempering behaviour of steel 88. The initial decrease in chromium content (Fig.21) was still observed, but the transformation occurred after only 3 h instead of 100 h.

DISCUSSION

Discussion of the constitutional work

A large proportion of the niobium in the steel is almost certainly present as niobium carbide even in the as-quenched state. This reduces the carbon available for combination with iron, chromium, and vanadium and consequently affects the constitutional diagram. Additions of 0·2%Nb would require only 0·025%C for total combination, leaving 0·175%C for combination with iron, chromium, and vanadium, and hence only small changes in the positions of the phase boundaries would be expected. However, in 1·0%Nb steels, 0·125%C would be required for combination with niobium and appreciable changes in the positions of phase boundaries would be anticipated.

The effect of carbon content on the positions of the $Cr_7C_3/Cr_7C_3+Cr_{23}C_6$ and the $Cr_7C_3+Cr_{23}C_6/Cr_{23}C_6$ boundaries in the Fe–Cr–C system have been investigated by several workers,[9–11] and the phase boundary shifts for the observed changes of 1·0%, 0·125%, and 0·025%C are given in Table III. Shaw and Quarrell[1] found that the $Cr_7C_3/Cr_7C_3+Cr_{23}C_6$ and $Cr_7C_3+Cr_{23}C_6/Cr_{23}C_6$ phase boundaries in 0·2%C chromium steels occurred at 7·0% and 7·9%Cr respectively. The calculated positions of these boundaries, after allowing for changes in the available carbon and the observed phase boundaries are given in Table IV.

Shaw and Quarrell[1] found $Fe_3C/Fe_3C+V_4C_3$ and $Fe_3C+V_4C_3/V_4C_3$ boundaries at 0·29%V and 0·65%V respectively. As Vogel and Martin[12] and Wever *et al.*[13] observed for both boundaries a shift of 0·6%V for a 0·1%C increase, shifts of 0·15% and 0·72%V would be expected on the addition of 0·2% and 1·0%Nb. This should be compared with the observed shifts of 0·3% and 0·6%V for the $V_4C_3/V_4C_3+Fe_3C$ boundary, and 0·15%V in the case of the $V_4C_3+Fe_3C/Fe_3C$ boundary for 0·2%Nb steels. Steels containing 1·0%Nb do not show a carbide phase field containing only Fe_3C.

TABLE V Effect of niobium on the $Fe_3C \rightarrow Cr_7C_3$ transformation

Steel no.	Steel composition, % Cr	V	Nb	C	Transformation, h Started	Completed
61	1·55	0·05	0·19	0·23	2–5	10–30
179	1·98	0·03	1·14	0·21	0·2	1

TABLE VI Effect of niobium on the $Cr_7C_3 \rightarrow Cr_{23}C_6$ transformation in the absence of V_4C_3

Steel no.	Steel composition, % Cr	V	Nb	C	Transformation, h Started	Completed
Shaw's 412[1]	8·41	0·75	...	0·21	110	240–500
Steel 85	9·11	0·85	0·20	0·24	100	400–1000
Steel 187	8·45	1·08	1·15	0·21	3	100

A movement of the $Cr_7C_3/Cr_7C_3+V_4C_3$ boundary to higher vanadium levels was not anticipated. However this boundary for Cr–V–Nb steels was almost parallel to that determined for niobium-free steels but occurred at higher vanadium contents. Smith[2] suggested that the solubility of vanadium in Cr_7C_3 increases when the chromium content exceeds 5·5%. This is caused by the gradual expansion of the Cr_7C_3 lattice to a limiting value above which there are sites large enough to accommodate the vanadium atoms. The Cr:C ratio of a 5·5%Cr 0·2%C steel is 27 and as niobium reduces the effective carbon content of the steel to about 0·1%, this critical Cr:C ratio should be reached at 2·7%Cr and hence the solubility of vanadium should, and does, increase sharply at this point.

Discussion of the tempering processes studied

The $Fe_3C \rightarrow Cr_7C_3$ *transformation*

Mechanism There is much confusion as to the mechanism by which this transformation takes place. The microstructures obtained in the early stages of tempering (Figs.9–11) show that the appearance of rod-like particles is associated with the first evidence of Cr_7C_3 in the X-ray photographs of extracted carbides. Thus it seems possible that the fine particles in Fig.9 (presumably Fe_3C) transform directly to Cr_7C_3 rodlets (Fig.10) which grow with continued tempering. This is supported by the gradual increase in chromium content of the carbide extract at the expense of the iron content, which Kuo[9] suggested was due to the gradual replacement of iron atoms in the Fe_3C lattice by chromium atoms until an *in situ* transformation occurs when the limiting concentration of chromium atoms has been exceeded.

However, from the evidence presented here it would be equally possible for the Cr_7C_3 rodlets to be separately nucleated after the resolution of the fine particles, the rodlets of Cr_7C_3 in the early stages being too small to give an X-ray diffraction pattern. Thus the results presented do not resolve the uncertainty as to the mechanism by which the $Fe_3C \rightarrow Cr_7C_3$ transformation occurs.

The effect of niobium on the $Fe_3C \rightarrow Cr_7C_3$ *transformation* The effect of niobium on this transformation can only be deduced from the effects observed by increasing the niobium content of the steel, as a niobium-free steel

TABLE VII Effect of niobium on the $Cr_7C_3 \rightarrow Cr_{23}C_6$ transformation in the absence of V_4C_3

Series	Steel no.	Steel composition, % Cr	V	Nb	C	Transformation, h Started	Completed
1	Shaw's 434[7]	7·95	1·15	...	0·19	110	110–240
	Smith's 434 A.[2]	7·86	1·14	...	0·23	100	300–600
	Steel 86	0·11	1·07	0·20	0·24	100	400–1000
2	Steel 434 A2[2]	7·66	1·27	...	0·20	150	300–600
	Steel 88	7·32	1·50	0·21	0·24	100	400–1000
	Steel 189	8·0	1·46	0·93	0·20	10	100

was not investigated. However, increased niobium content appears to accelerate the transformation as can be seen from Table V. However, this might be due to the higher chromium content of steel 179. When the concentration of chromium atoms in the Fe_3C lattice exceeds a certain limiting value, the Fe_3C phase becomes unstable and the transformation to Cr_7C_3 occurs. Niobium, by combining with the carbon, reduces the amount of Fe_3C present; thus the chromium in the matrix has fewer Fe_3C molecules to which it can diffuse, and thus one would expect a more rapid concentration of chromium atoms in the Fe_3C lattice, leading to an earlier transformation.

The $Cr_7C_3 \rightarrow Cr_{23}C_6$ *transformation*

Mechanism There is general agreement that at temperatures near to 700°C this transformation occurs *in situ*, and the results of the present investigation support this mechanism as there is no evidence for the resolution of the large Cr_7C_3 particles before transformation.

The decrease in chromium content of the carbide during transformation observed by Shaw and Quarrell also occurred in the present investigation. This is a result of each six carbon atoms being associated with 23 metal atoms in $Cr_{23}C_6$ compared with 14 metal atoms in Cr_7C_3. Therefore metal atoms from the matrix are absorbed to form the $Cr_{23}C_6$ lattice and the proportion of chromium in the carbide extract falls.

The effect of niobium on the $Cr_7C_3 \rightarrow Cr_{23}C_6$ *transformation* Niobium appears to accelerate the $Cr_7C_3 \rightarrow Cr_{23}C_6$ transformation both in the presence and absence of V_4C_3 (Tables VI and VII). Shaw and Quarrell[1] suggested that at least 80% of the metal atoms in Cr_7C_3 had to be chromium or chromium+vanadium before the transformation to $Cr_{23}C_6$ occurred, and that this provided the minimum concentration of chromium atoms necessary to stabilize the $Cr_{23}C_6$ structure. When niobium is present it reduces the 'available carbon' and thereby reduces the amount of Cr_7C_3 formed, hence more chromium is left in the matrix and this results in a more rapid concentration of chromium atoms in the Cr_7C_3, the critical chromium content (80%) is reached at an earlier stage, and transformation is accelerated.

ACKNOWLEDGMENTS

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An electron microscopical investigation of the tempering of 18–4–1 high-speed steel

C. H. White and R. W. K. Honeycombe

SYNOPSIS

An electron microscopical examination has been made of the structures which occur during the tempering of 18–4–1 high-speed steel. The secondary hardening phenomenon is shown to arise from the precipitation of an alloy carbide ($M_{23}C_6$ type) in the martensitic needles. A similar precipitation observed in the retained austenite does not appear to contribute to the hardening process.

1820

INTRODUCTION

IN THE as-quenched condition, high-speed steel containing 18%W, 4%Cr, and 1%V comprises a matrix of martensite and about 15–20% retained austenite with a dispersion of η carbide which will be referred to as M_6C. This carbide has a variable composition where M is primarily iron and tungsten, but chromium and vanadium are also taken into solid solution. The as-quenched steel is hard, highly stressed, brittle, and dimensionally unstable, but on tempering, strength, toughness, and stability are promoted without appreciable loss in hardness.

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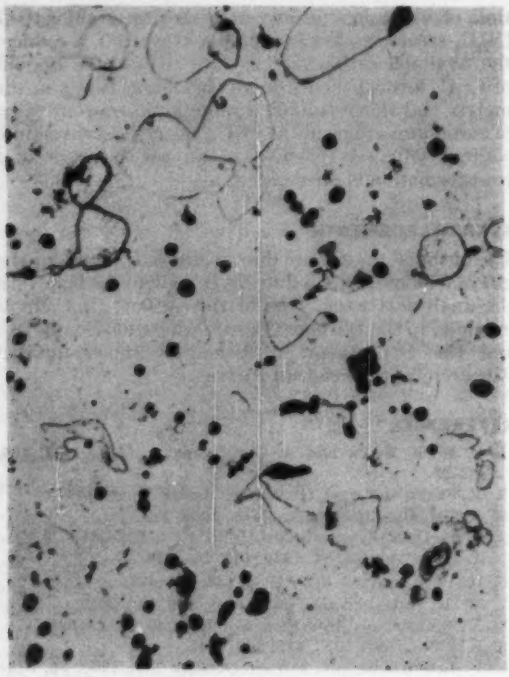
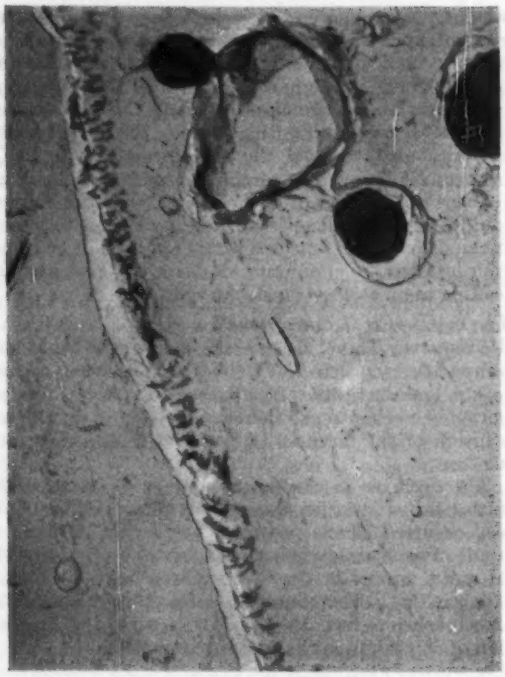
The tempering of high-speed steel has attracted much attention in the past.[1–4] Cohen and Koh[5] carried out a detailed investigation as a result of



1 *18–4–1 high-speed steel annealed, carbon extraction replica* ×12000



2 *18–4–1 high-speed steel as-quenched, carbon extraction replica* ×17000

which they proposed that the course of transformation during tempering took place in four overlapping stages:

(i) precipitation of cementite from the martensite forming a highly alloyed ferritic matrix
(ii) precipitation from the residual austenite of complex carbides
(iii) transformation of the residual austenite
(iv) resolution of cementite in the ferritic matrix followed by precipitation of complex alloy carbides.

They have suggested that stage (i) accounts for the initial softening, while the secondary hardening was adjudged to result from stages (ii) and (iii). Stage (iv) was assumed to occur only at high temperatures, and to account for the rapid drop in hardness. Another viewpoint, however, has been that the secondary hardening phenomenon may be due to the precipitation of alloy carbides in the ferritic matrix.

Cohen and Koh's assumption that the first stage involves precipitation of cementite is based on thermomagnetic measurements. Kuo[6] has been unable to detect Fe_3C in X-ray photographs of extracts from specimens tempered at low temperatures, but has suggested that this could be due to the overshadowing effect of M_6C. On X-ray examination of extracts from specimens tempered at 600–800°C, Kuo found M_6C between 600° and 650°C, M_6C and W_2C between 675° and 725°C, and at 800°C only M_6C again. On the other hand, as a result of X-ray examination, Goldschmidt[7] gave the following sequence on tempering, $M_6C \rightarrow$ transitional carbide $\tau \rightarrow M_{23}C_6$, the transitional carbide being a previously unknown phase.

The main disadvantage of the X-ray analysis of extracts from high-speed steel is that a major proportion will be massive M_6C carbide undissolved in the prior heat treatment, whereas the secondary carbides will be a much finer dispersion which may not always give clear diffraction lines. In the present work, the carbon extraction replica technique was used in conjunction with electron microscopical and electron diffraction examination. As the primary M_6C carbide was not usually extracted in the replica, the secondary carbides could be examined more closely without interference.

EXPERIMENTAL DETAILS

Material

The steel used in the investigation was provided by Edgar Allen and Co. Ltd and consisted of three $\frac{1}{2}$-in square bars from the same case having the following typical analysis %:

C	Si	S	Mn	W	Cr	V	Mo	Ni
0·66	0·10	0·035	0·31	18·62	4·57	1·46	0·46	0·17

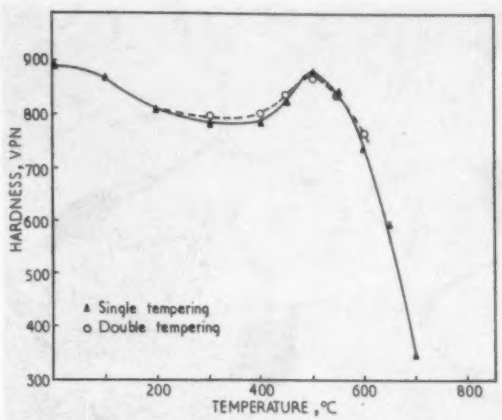
It was received in the as-rolled and annealed condition.

Heat treatment

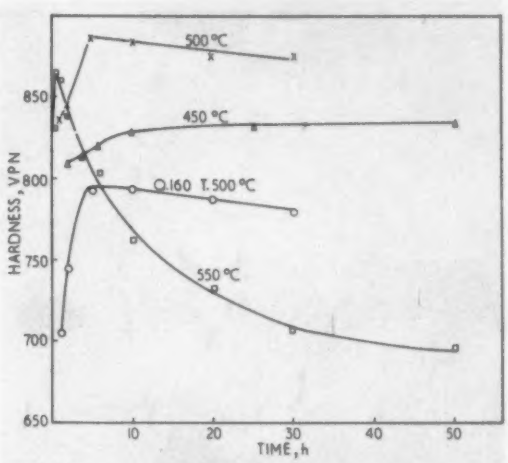
Specimens $\frac{1}{2}$-in long were preheated at 860°C for 1 h before austenitizing 2 min at 1280°C in a neutral salt bath followed by oil quenching. The subsequent tempering treatments in the range 200–800°C were carried out in salt baths followed by air cooling.

Electron microscopy

The specimens were ground to remove any decarburization, then mechanically polished. This was followed



3 *18–4–1 high-speed steel isochronal tempering curves*



4 *18–4–1 high-speed steel isothermal tempering curves*

by electropolishing in an electrolyte containing 50 ml perchloric acid (sg 1·54) and 950 ml glacial acetic acid using a stainless-steel cathode. An applied voltage of 64 V and a current density of 1 A/cm² were required, while the time of polishing was 10–20 s. The surface was then lightly etched in Vilella's reagent.

A thin (100–200 Å) film of carbon was evaporated on the surface *in vacuo* and subsequently loosened by etching for about 1½ min in a 5% Nital solution containing a few drops of hydrofluoric acid. The specimens were then rinsed in alcohol and finally the films were floated off in distilled water. Often difficulty was experienced in removing replicas from samples; in these cases, after the above treatment had failed, the specimens were given a brief electropolish in 10% Nital solution. Current densities of 1–1·5 A/cm² were used with applied voltages of 100 V. A judicious combination of electropolishing and etching before carbon deposition was the main essential for satisfactory replica preparation.

The replicas were examined in an EM3 electron microscope (resolution 50 Å) while an EM3A (resolution 30 Å) instrument was used for a few critical replicas.

Electron diffraction

It was possible to obtain transmission electron diffraction patterns from small areas several microns in diameter, selected by use of an aperture. Standardization was essential, and this was done by photographing a pattern from an evaporated thallium chloride film before and after other diffraction photographs had been taken. The d values calculated for the patterns were then corrected using the accurately known d values of thallium chloride.

X-ray diffraction

Electrolytic extracts were prepared using a citrate cell, and after centrifuging and washing were examined in a 9-cm powder camera using unfiltered chromium radiation. Photographs were compared with standard patterns obtained from known carbide extracts.

EXPERIMENTAL RESULTS

Annealed and as-quenched specimens

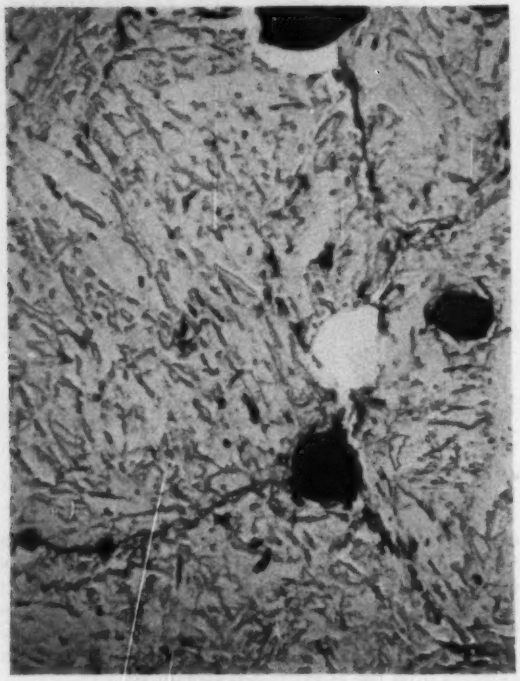
General microscopical examination revealed little evidence of carbide stringers and the material appeared to be quite uniform in structure. The small specimens used were thus considered to be representative of the bulk material: X-ray patterns of electrolytic extracts from the annealed steel showed M_6C lines and weak $M_{23}C_6$ lines, while only M_6C lines were found in extracts from the as-quenched specimens.

Electron microscopical examination of the annealed steel revealed the M_6C as a relatively coarse distribution of spheroidal particles, 75% of which were between 1 and 2 μ dia. with a few much larger particles. These M_6C carbides were not usually extracted in the replicas but their outline remained (Fig.1). The finer dispersion shown in Fig.1 is the $M_{23}C_6$ carbide with an average size of 2000–3000 Å. This latter precipitate was absent in the as-quenched steel (Fig.2) which revealed primarily the distribution of M_6C; however, on prolonged etching a fine precipitate was extracted from the grain boundaries (Fig.2) which gave electron diffraction patterns corresponding to that of vanadium carbide. This carbide was also detected in replicas taken from fracture surfaces.

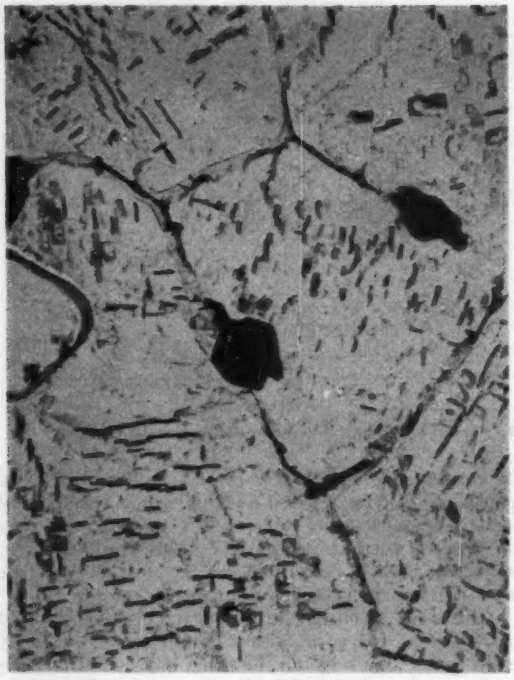
Hardness changes in the range 100–700°C

Specimens were tempered in the range 100–700°C for 5 h; the hardness results measured at room temperature are shown in Fig.3. The as-quenched hardness of 900 DPN dropped to a minimum of just below 800 DPN on tempering at 400°C, then rose sharply to a secondary peak approaching 900 DPN at 500°C. Increasing the temperature further caused a rapid drop in hardness. The dotted curve represents results obtained by a double tempering treatment of two 2½-h periods between which the specimens were air-cooled to room temperature; this curve is practically indistinguishable from the normal curve.

The isothermal hardness data (Fig.4) confirm that the optimum hardness is developed after 5 h at 500°C, and that the hardness is maintained at this temperature. However, after treatment at 550°C, the hardness rapidly falls from a peak of about 870 DPN to 700 DPN after 50 h. Tempering at 450°C on the other hand, does not produce full hardening even after 100 h.



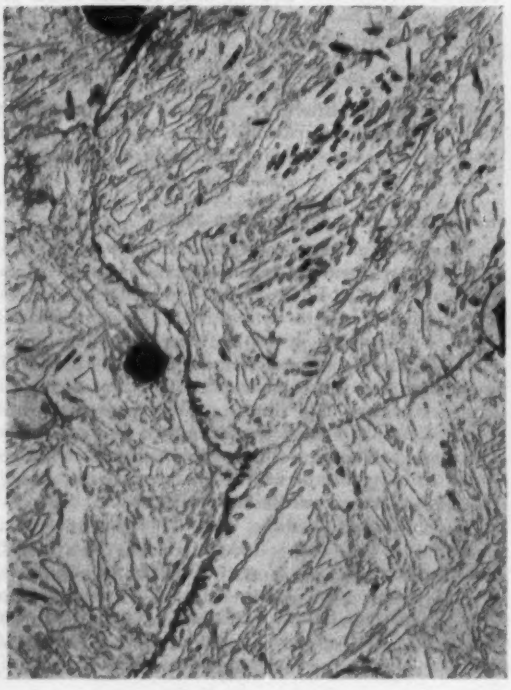
5 *18–4–1 high-speed steel tempered 5 h at 300°C, carbon extraction replica* ×12000



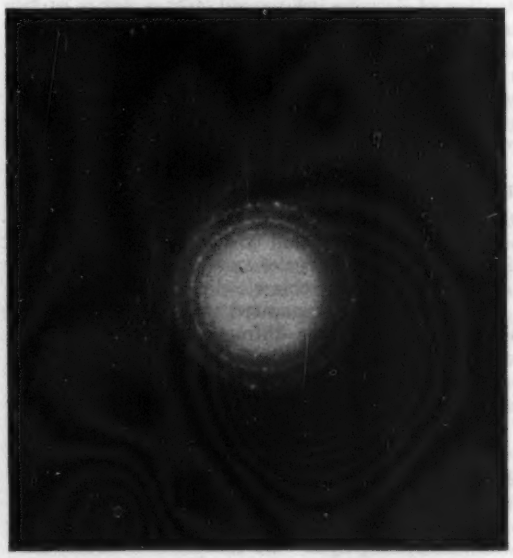
7 *18–4–1 high speed steel tempered 5 h at 400°C, carbon extraction replica* ×12000

Electron microscopical and electron diffraction results

The martensitic structure of the as-quenched steel was not easily revealed (Fig.2); however, on tempering in the range 300–400°C the martensite was much more readily etched (Fig.5). Electron diffraction examination of replicas from specimens tempered at 300°C did



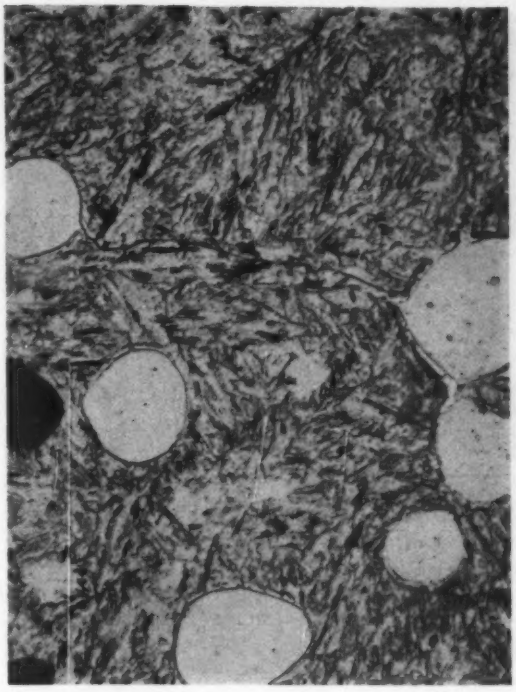
a



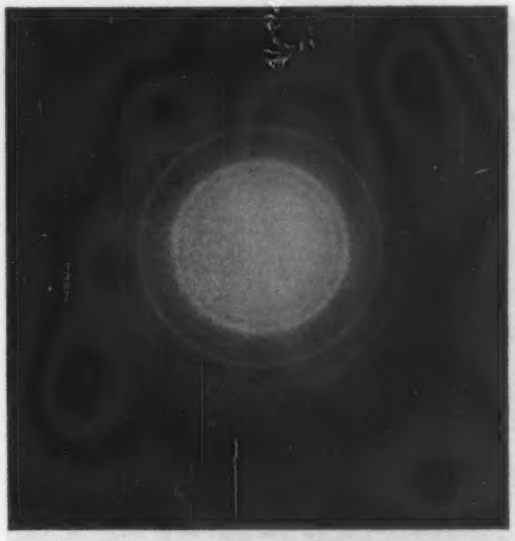
b

6(a) *18–4–1 high-speed steel tempered 5 h at 400°C, carbon extraction replica* ×12000

(b) *18–4–1 high-speed steel electron diffraction pattern obtained from precipitate shown in Fig.6a*



8 *18–4–1 high-speed steel tempered 5 h at 550°C, carbon extraction replica* ×12000



9 *18–4–1 high-speed steel electron diffraction pattern obtained from specimens tempered for 5 h at 550°C*

not yield a pattern from which identification could be made. It was thus not possible to decide whether Fe_3C was precipitated at this early stage.

On tempering at 300–400°C a Widmanstätten plate-like precipitate was observed in areas not exhibiting a martensitic structure (Fig.6*a*). This is considered to be carbide precipitation within small areas of retained austenite. Figure 6*b* is an electron diffraction pattern from such a region corresponding to the $M_{23}C_6$ type carbide (col.3, Table I). The precipitate was fairly coarse and the diffraction rings spotty. Occasionally much larger areas occupying several grains were detected; these were presumably due to segregation of alloying elements. Figure 7 shows the precipitation observed in such austenitic regions after tempering 5 h at 400°C. The electron diffraction patterns from this precipitate are slightly different from that in Fig.6*b* and could possibly be a mixed pattern of $M_{23}C_6$ and VC.

In the range 450–500°C, the martensitic needles, previously well defined, became diffuse, but at this stage there was no clear evidence of a new precipitate in the electron micrographs (Fig.8). After tempering at 550–600°C martensitic regions yielded electron diffraction patterns which corresponded to $M_{23}C_6$. The pattern closely resembled those obtained from the precipitate formed in the retained austenite at 400°C except that the rings were continuous indicating a much finer particle size (Fig.9). Table I shows typical *d* values determined from selected area electron diffraction photographs which have been standardized against thallium chloride. The *d* values as given in the ASTM index for $Cr_{23}C_6$ and M_6C are also shown, but it should be emphasized that although the crystal structures are the same, the chemical composition of the carbides in the 18–4–1 steel are very different. This would undoubtedly influence the *d* values.

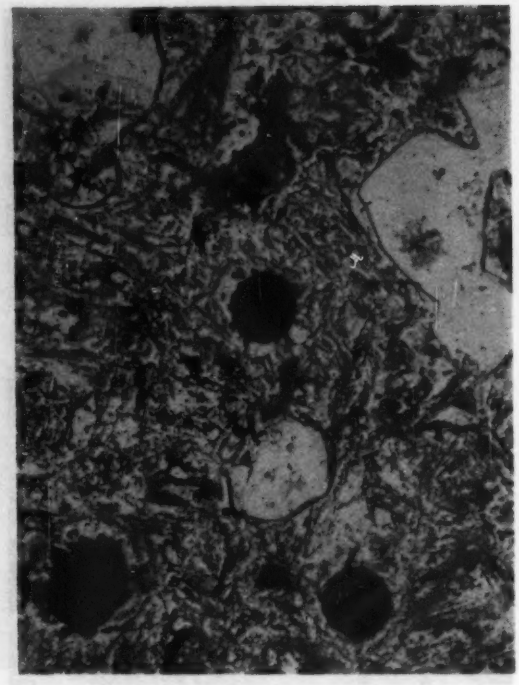
The $M_{23}C_6$ precipitate in the retained austenite was first detected at 300°C. The particles coarsened rapidly

TABLE I Measurements of d values from 18–4–1 replicas, Å

1	2	3	4	5	6
	Specimen				
	Tempered 5 h at 400°C	Tempered 4 h at 450°C	Tempered 5 h at 600°C	Tempered 5 h at 700°C	
$Cr_{23}C_6$ ASTM index	Precipitate in segregated areas	Precipitate in austenite	Precipitate in ferrite	Precipitate in ferrite	M_6C ASTM index
3·21					3·31
3·07		3·05			
2·66	2·65	2·64	2·65	2·64	2·75
2·44	2·52		2·51	2·52	2·53
	2·45				
2·38	2·38	2·38	2·38	2·38	2·25
2·17	2·18	2·18	2·18	2·19	2·12
2·05	2·06				
1·88		1·93			1·95
1·80		1·78	1·77	1·79	1·84
	1·78				
1·77					1·74
1·68		1·67		1·67	1·66
1·62					
1·60		1·60			
1·49	1·53	1·54	1·55	1·55	1·54
1·48					1·43
1·38		1·39		1·38	1·38
1·34	1·34	1·34	1·32	1·33	1·35
1·33					
1·29	1·28		1·28	1·28	1·30
1·25		1·25			1·27
1·23					
1·22					1·21
1·19					1·20
1·17					1·18
1·08*	1·08	1·08	1·11	1·09	1·11
1·07			1·05		1·08
0·99	0·99		1·00	0·99	1·07
0·97					1·06
0·96				0·96	1·03
0·94	0·95		0·95		1·01
0·93					0·995
0·91					
0·90			0·89	0·89	

* This and subsequent values from Goldschmidt.[11]

10 *18–4–1 high-speed steel tempered 5 h at 600°C, carbon extraction replica* ×50000



11 *18–4–1 high-speed steel tempered 5 h at 650°C, carbon extraction replica* ×12000

in the early stages but over the range 400–550°C remained of relatively constant size, about 500 Å thick and about 1500–3000 Å long. As the secondary hardening peak only became marked at 500°C, it seems clear that it is not closely related to changes in the retained austenite.

While the etching characteristics of the martensite continued to change in the range 450–500°C it was not until 600°C (Fig.10) that fine precipitate particles from the martensite matrix were resolved in the replicas. The coarse particles are probably those originating from the austenitic regions. The precipitate in the martensite became much clearer at 650°C (Fig.11). Thus the precipitate coarsens very slowly, which contrasts markedly with the behaviour of the $M_{23}C_6$ formed in the austenitic regions. At 700°C the residual acicular structure finally disappeared leaving a ferritic matrix containing a much coarser secondary carbide dispersion (Fig.12). The primary M_6C carbides remained as impressions in the replica. Electron diffraction examination of replicas from specimens tempered at 650–700°C gave patterns corresponding to $M_{23}C_6$. At 700°C the pattern was very spotty indicating a substantial coarsening of the precipitate: Fig.13 is a typical pattern from the replica of Fig.12.

X-ray examination of electrolytic extracts

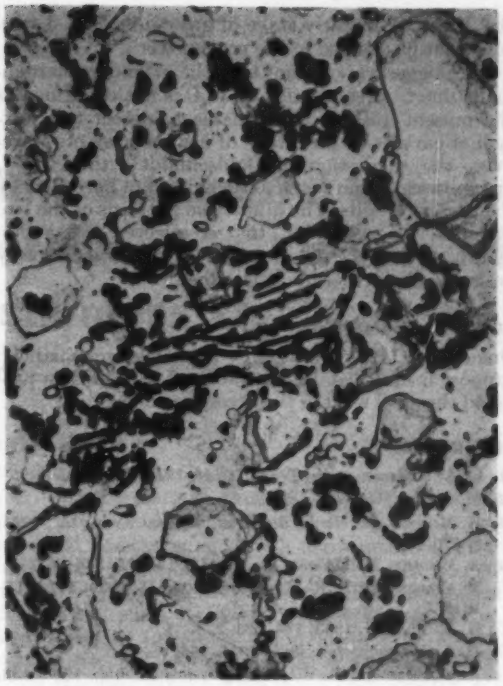
Extracts were prepared from the annealed and as-quenched specimens as well as from those tempered 5 h at 400°, 500°, 600°, and 700°C. In all cases, lines corresponding to M_6C were obtained and only in the annealed sample were very weak $M_{23}C_6$ lines observed. It is clear that the X-ray diffraction and electron diffraction results are both selective. The X-ray method detects the massive primary M_6C which is too coarse to give transmission electron diffraction patterns even when sufficient of the coarse particles is extracted in the replicas. On the other hand, the $M_{23}C_6$ particles formed in the martensite are extremely fine in the range 500–600°C; the fact that they were not resolved in the electron micrographs suggests that they were less than 100 Å dia. However, they yielded electron diffraction patterns with continuous rings except at 700°C when the patterns had become spotty.

The carbide extracts have recently been re-examined using a low-angle focusing camera[12] and Co-radiation rendered monochromatic by a bent quartz crystal.

In the as-quenched condition only M_6C lines were observed. In the annealed condition $M_{23}C_6$ was clearly indicated whereas with the 9-cm camera the lines were very weak. Tempering for 5 h at 600°C again showed only M_6C but at 700°C, $M_{23}C_6$ lines although weak, were definitely indicated. In none of the extracts could W_2C or VC be detected.

Decomposition of retained austenite

In order further to determine the role of austenite during the tempering process, specimens were austenitized at 1280°C, then quenched into a bath of Wood's Metal at 160°C and held for 2–3 min. The specimens were then immediately transferred to a salt bath at 500°C and held for periods from 1 to 30 h. At 160°C, from the published isothermal diagram, only



12 *18–4–1 high-speed steel tempered 5 h at 700°C, carbon extraction replica* ×12000

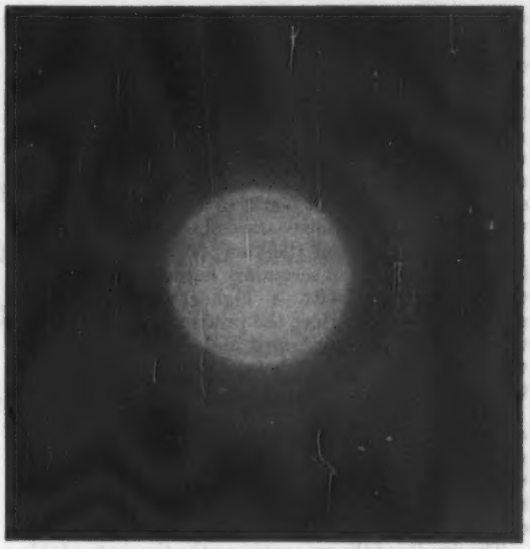
40% of the austenite would be expected to transform to martensite, so there should be a much higher concentration of retained austenite. The change in hardness on subsequent tempering at 500°C is shown in Fig.4 from which it can be seen that the maximum hardness of 800 DPN is reached after 5 h.

Electron microscopic examination revealed large areas of retained austenite in which extensive precipitation had already taken place after 1 h (Fig.14) at this temperature, although at this stage no substantial secondary hardening had occurred.

DISCUSSION

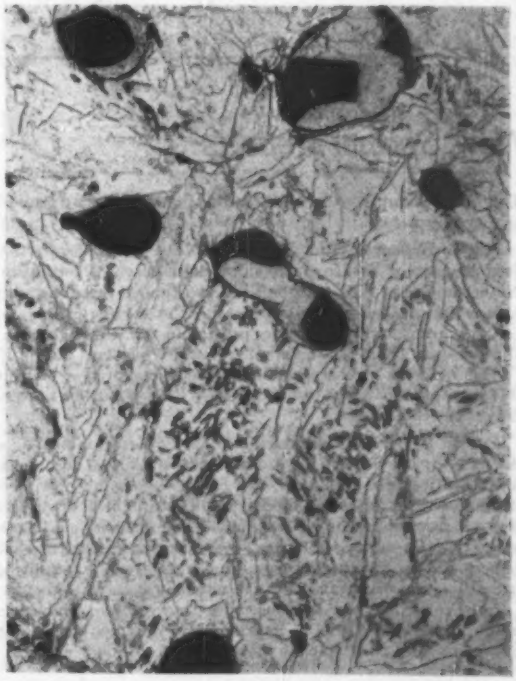
In the literature much importance has been attached to the presence of 15–20% retained austenite in the as-quenched 18–4–1 high-speed steel. The present work has shown that during tempering this austenite precipitates carbide of the $M_{23}C_6$ type as a Widmanstätten array at temperatures as low as 300°C. It is likely that the austenite in the as-quenched steel is deformed as a result of the stresses associated with the quench and with the formation of martensite, and moreover that it has a high concentration of entrapped vacancies. The latter would accelerate diffusion of metal atoms necessary for the nucleation of the carbide, while the high dislocation population of the austenite regions would provide sites of easy nucleation where the precipitate could form.

Notwithstanding the clear evidence for precipitation within the retained austenite, this precipitation was fully developed long before the onset of secondary hardening. For example, after 5 h at 400°C the $M_{23}C_6$ precipitate plates in the austenite were already 1500–



13 *18–4–1 high-speed steel. Electron diffraction pattern obtained from precipitate shown in Fig.12*

3000 Å long and approximately 500 Å thick, although no secondary hardening had taken place. Likewise, at 450°C precipitation in the austenite was complete after 1 h, while little secondary hardening occurred up to 50 h. The precipitate in the austenite regions showed



14 *18–4–1 high-speed steel. Quenched from austenitizing temperature to 160°C, held for 2–3 min and then tempered for 1 h at 500°C. Carbon extraction replica* ×12000

no apparent growth over the secondary hardening range whereas the etching characteristics of the martensite changed markedly. It was not possible to resolve any precipitate in the martensite at this stage; however, selected area electron diffraction patterns were obtained which showed that $M_{23}C_6$ type carbide was present after 5 h at 550°C, just beyond the secondary hardening peak. Microscopic examination of specimens tempered at 600°C revealed the precipitate which had by this time coarsened considerably.

Further support for the viewpoint that the austenite is not the cause of secondary hardening comes from the experiments with a higher concentration of retained austenite. Here the precipitation of $M_{23}C_6$ in the austenite was confirmed and again it was shown that this was complete before substantial hardening took place.

The fact that double tempering treatments yielded almost the same hardness results as the single treatment suggests again that transformation of the retained austenite, this time to martensite on cooling, has little effect on the secondary hardening phenomenon.

The results of the present investigation indicate that 18–4–1 high-speed steel undergoes secondary hardening in a similar way to that postulated for low-alloy martensitic steels by Seal and Honeycombe,[8] and Smith and Nutting,[9] who have suggested that a coherent precipitation of alloy carbides (e.g. VC, Mo_2C) is responsible. At optimum secondary hardness in low-alloy steels the plate-like precipitates are about 25 Å thick and 100–200 Å in length so they can only be resolved with microscopes of extremely high resolution (10–20 Å). For this reason, the exact morphology of the $M_{23}C_6$ at an early stage of growth in 18–4–1 steel could not be decided in the present work.

The suggestion of Kuo[6] that the secondary hardening is due to precipitation of W_2C is not confirmed as the present authors were unable to detect this hexagonal carbide at any stage of heat treatment. Moreover, the suggestion of Goldschmidt[10] that $M_{23}C_6$ precipitates within the M_6C carbide is not borne out by the present results. The diffraction patterns of the two carbides are so similar, that a selective extraction method of the type referred to in this paper seems very desirable for further investigations.

ACKNOWLEDGMENT

One of us (C.H.W.) gratefully acknowledges financial support from Edgar Allen and Co. Ltd, who also provided the steel used in the investigation.

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New Special Reports

The latest volumes to be published in the Institute's Special Report Series are the proceedings of two symposia held in London in May 1960.

Special Report 67 'Production of wide steel strip' reports the symposium on wide strip which formed part of the Institute's Annual General Meeting in 1960. The papers, from Italy, the Netherlands, the UK, and the USA, are divided into five groups, dealing with future requirements of user industries, steelmaking for wide strip, hot rolling, cold rolling and heat-treatment, and coatings respectively. They are printed in full, together with a report of the lively discussions at the meeting. There is a foreword from the President, Mr W. F. Cartwright, D.L., J.P.

This report is a quarto volume of 196 pages, printed on imitation art paper and illustrated with 98 line diagrams and 57 photographs. Copies may be obtained, price £3 5*s* 0*d* each (postage 1*s*) from the Secretary.

Special Report 68 'The determination of gases in metals' is a report of the symposium organized last May by the Society for Analytical Chemistry in conjunction with The Iron and Steel Institute and The Institute of Metals. This highly successful joint meeting was based on a series of papers dealing with the latest developments in the methods of gas determination in both ferrous and non-ferrous metals, including vacuum fusion, carrier-gas methods, activation analysis, emission spectrometry, isotope dilution, and internal friction methods. There are also excellent review papers on the three main gases, oxygen, hydrogen, and nitrogen. As with the wide strip proceedings, there is a full report of the discussions at the meeting.

Octavo format has been used for this volume, which comprises 316 pages and 8 plates; it is amply illustrated with line diagrams, and provided with an attractive dust jacket. Copies may be obtained, price £3 3*s* 0*d* each (postage 1*s*) from the Secretary.

Microstructural causes of heat-affected zone cracking in heavy section 18-12-Nb austenitic stainless steel welded joints

N. E. Moore, B.Sc. and J. A. Griffiths

SYNOPSIS

*The widespread difficulties encountered both in the UK and elsewhere in the fabrication of 18–12–*Nb *stainless steel, and the failures in service of steampipes and similar welded components have led to numerous investigations. A recent investigation by Truman and Kirkby has indicated that the cracking could be associated with abnormally low hot ductility values resulting from certain temperature and strain conditions, such as may be imposed on the heat-affected zone of the parent metal close to the weld, i.e. where cracking has been experienced.*

The investigation reported here is complementary to that of Truman and Kirkby. An electron microscope study of their test specimens has been made and the marked changes in hot ductility reported by them are explained in terms of temperature and strain-induced microstructural changes.

*The microstructural changes causing embrittlement with the 18–12–*Nb *steel were not observed on comparative tests with a steel of the 17–11–*Mo *type.* 1897

INTRODUCTION

THE TREND TOWARDS steam temperatures over 1050°F (565°C) in steam generating plant and in steam turbines has necessitated the use of a steel readily weldable and possessing good high temperature oxidation and creep resistance. An obvious choice was the 18–12–Nb (Type 347) austenitic stainless steel; but unfortunately since its initial application to parts of heavy section for steam power plant some 12 years ago, it has been found susceptible to 'heat-affected zone' cracking, cracks being found after welding, after stress relieving, or after a short period of high-temperature service.[1–6]

Characteristically, these cracks appear to start at, or very close to, the outside surface of a welded steampipe or similar component, at the fusion boundary or in the adjacent parent metal, and they propagate inwards more or less parallel to the weld in an intercrystalline manner.

A great deal of investigational work has been done on the high-temperature tensile properties, ductility characteristics and creep rupture strength in an endeavour to understand the mechanism of failure. Reference is made below to some papers describing work of considerable interest, but in general they have not provided convincing and complete answers to the questions arising.

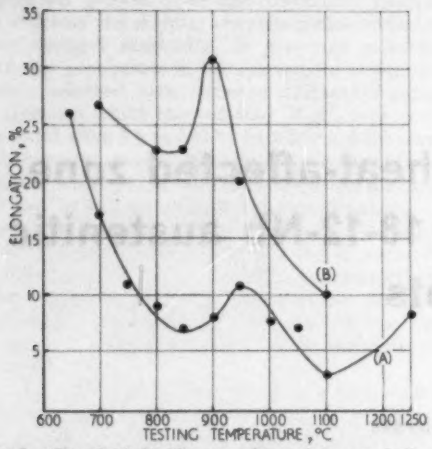
A recent investigation by Truman and Kirkby[20] of the Brown Firth Research Laboratory in which they take account not only of the high temperature attained in the heat-affected zone close to the weld, but also of the contraction strains occurring on subsequent cooling, has given results which appear to be highly significant. These show that when both these factors are taken into account the hot ductility of the parent metal close to the weld can be so reduced as to suggest that the mechanism involved is also responsible for weld cracking.

The work reported in the present paper is complementary to that of Truman and Kirkby. A study has been made, using the electron microscope, of the structures developed in their test specimens; and the microstructural effects accompanying the marked changes in hot ductility which they demonstrated have been determined.

Truman and Kirkby simulated the high temperature reached in the heat-affected zone by a solution treatment from 1350°C followed by hot tensile tests at different temperatures to simulate the hot straining experienced locally by the metal on cooling after welding. The curves shown in Fig.1 are selected as representative of the results obtained. Note the marked reduction in ductility shown by the hot tensile tests at 850°C and 1100°C following a high temperature treatment, such as would apply to the heat-affected zone. This drop became progressively more marked as the solution treatment temperature increased. It was also found (*see* curve *B*) that while the 850°C minimum in the ductility curve could be almost eliminated by ageing without strain at 850°C before carrying out the hot tensile test, the low ductility trough at 1100°C persisted.

Evidence concerning microstructural changes consistent with Truman and Kirkby's experimental results has been obtained and is presented below. The

Paper MG/J/75/60 of the High-temperature Steels Committee and Joint BISRA–ERA Steelmakers' Panel of the Metallurgy (General) Division of the British Iron and Steel Research Association, first received on 20 August 1960 and in its final form on 24 October 1960. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body. The authors are at Associated Electrical Industries (Manchester) Ltd, Manchester.



1 *Hot ductility of 18–12–Nb austenitic stainless steel. Curve* A, *ST 1050°C—1 h AC, ST 1350°C—3 min AC followed by tensile testing. Curve* B *solution treated as above and aged for 3 h at 850°C before tensile testing*

microstructural work is mainly concerned with the tests on 18–12–Nb steel referred to above, but some test pieces of 17–11–Mo type steel, which were found by Truman and Kirkby not to exhibit the same loss of ductility, have also been examined.

PREVIOUS WORK

From work carried out on this steel in the United States[1,7,10,13,14,17,21] it has been generally concluded that the formation at high temperatures of a liquid phase at the grain boundaries caused loss of ductility in the heat-affected zone near the bulk solidus temperature. This was thought to give rise to a hot short type of intergranular failure but visible signs of liquation have only been reported at temperatures down to 1370°C[22] and Truman and Kirkby found no such evidence at 1350°C. While, therefore, grain boundary liquation may be the cause of some hot tearing it does not explain the loss of ductility found by Truman and it is unacceptable as a complete explanation of the cracking experienced in the heat-affected zone of 18–12–Nb welded joints. It could not in any case account for cracking on stress relieving or in service. Other workers have advanced the theory of a stress-rupture type failure, occurring in the presence of residual stresses set up during welding heavy section pipes under conditions of severe restraint.[1,16,18] Puzak,[7] while thinking that cracking was due to hot shortness developed near the solidus by the formation of a fusible grain boundary film, concluded that crack propagation occurred at temperatures in the region of 850°C where he found Type 347 material suffered a drop in ductility. Hueschkel[16] working on all weld-metal test pieces also detected a ductility trough in the region of 850°C. Following high-temperature solution treatments and ageing from 600°C to 1200°C, Guessier and Castro[19] observed brittle tendencies in niobium stabilized steels during impact testing at −180°C. The trough observed after ageing at 600–700°C was attributed to chromium carbides formed at the grain boundaries while that found after ageing at 900–1000°C was thought to be due to niobium carbide precipitation. Reduced ductility during hot tensile testing at 1000–1050°C was attributed to niobium carbides formed during the deformation process.

TABLE I Hot tensile testing conditions for 18–12–Nb steel

Specimen	Heat treatment	Tensile testing temp., °C	Elongation, %
A	ST 1350°C, 3 min, AC	650	26·5
B	ST 1350°C, 3 min, AC	700	17·5
C	ST 1350°C, 3 min, AC	750	11·0
D	ST 1350°C, 3 min, AC	800	9·0
E	ST 1350°C, 3 min, AC	850	Deformed 1
F	ST 1350°C, 3 min, AC	850	6·0
G	ST 1350°C, 3 min, AC	900	8·5
H	ST 1350°C, 3 min, AC	950	10·5
I	ST 1350°C, 3 min, AC	1000	8·0
J	ST 1350°C, 3 min, AC	1050	7·0
K	ST 1350°C, 3 min, AC	1100	3·5
L	ST 1350°C, 3 min, AC	1200	9·5
M	1350°C, AC+3 h at 850°C AC	700	27·0
N	1350°C, AC+3 h at 850°C AC	800	23·0
O	1350°C, AC+3 h at 850°C AC	850	22·5
P	1350°C, AC+3 h at 850°C AC	900	30·0
Q	1350°C, AC+3 h at 850°C AC	950	20·0
R	1350°C, AC+¼ h at 850°C AC	...	...
S	1350°C, AC+1 h at 850°C AC	...	...
T	1350°C, AC+3 h at 850°C AC	...	...

ST = Solution treatment AC = Air cooled
All specimens were originally solution treated at 1050°C for one h and air cooled.

EXPERIMENTAL

Material

The steels used in Truman and Kirkby's experiments had the following cast analyses:

Type	%C	%Si	%Mn	%Cr	%Ni	%Nb	%Mo
18–12–Nb	0·09	0·73	1·37	17·28	11·73	0·9	...
17–11–Mo	0·05	0·36	1·53	16·82	10·38	...	2·2

The specimens examined in the investigation reported here were provided by Messrs Truman and Kirkby and were mainly those of the 18–12–Nb type giving the ductility results shown in Fig.1, which reproduces two of their curves. For comparative purposes test pieces of the 17–11–Mo type steel were also examined after tensile testing at 850°C.

To simulate the effect of the high temperatures attained in the heat-affected zone of weldments, specimens of ½-in dia. bar were solution treated for 1 h at 1050°C with air cooling, followed by a further solution treatment for 3 min at 1350°C. Tensile tests were then carried out at the temperatures indicated in Table I employing specimens machined to 0·1795 in. dia. These were heated to the testing temperature in 15–20 min and broken in 4–8 min.

Metallographic examination

The specimens were polished mechanically and etched electrolytically in saturated aqueous oxalic acid for direct examination with the optical microscope. The electron microscope was used to study formvar–carbon and carbon extraction replicas. Saturated aqueous oxalic acid was used as an extraction etch, but in some cases a two-stage extraction etching process was employed using in turn glyceregia and oxalic acid, to facilitate the extraction of large grain boundary carbides.

RESULTS

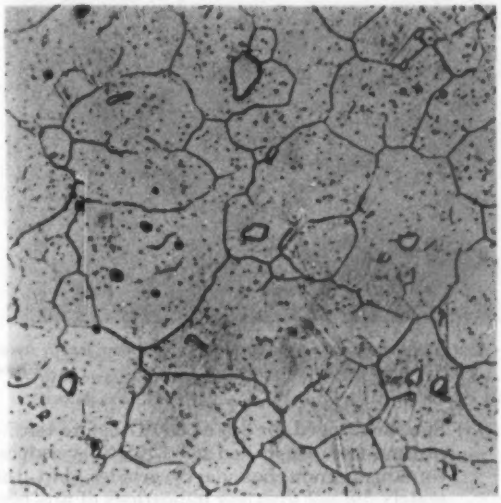
Structures shown by the optical microscope

Effect of solution treatment The effect of a 3 min solution treatment at 1350°C on a specimen previously

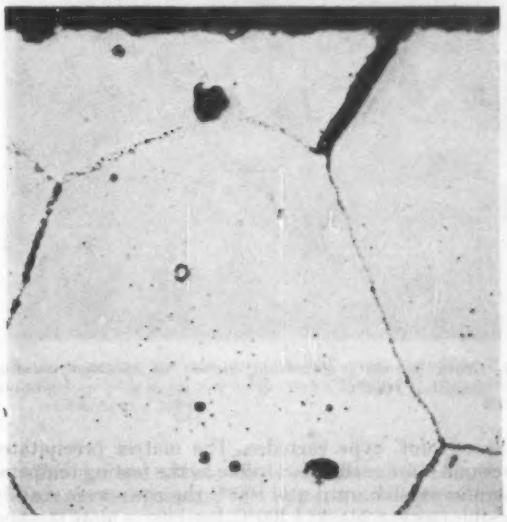
solution treated at 1050°C, was to increase the ASTM grain size index from 6 to 1 and partially dissolve some of the large niobium carbide particles (Figs.2*a* and *b*). There also appeared to be a greater number of the small grain boundary carbides present after the high-temperature solution treatment.

Effect of straining after solution treatment The specimens solution treated at 1350°C and then broken in tension at 650°, 700°, and 750°C showed increasing grain boundary precipitation as compared with the solution treated specimens, but the matrix still appeared featureless except for a random distribution of 'dot' type niobium carbide particles.

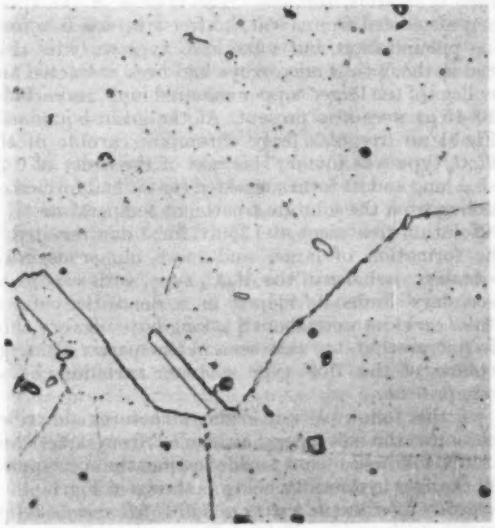
As the testing temperature was raised from 800°C to 950°C the pattern of grain boundary carbides changed from an almost continuous chain of precipitates to one of separate resolvable particles. In the matrix, at a testing temperature of 800°C very faint diffuse rows appeared. Figure 2*c* shows a specimen strained 1% at 850°C and indicates the faint matrix rows and the type of shallow intergranular crack formed even after very small amounts of deformation. These rows became more discernible at higher testing temperatures. At testing temperatures above 1000°C, considerably fewer grain boundary carbides were seen, although they were still present at 1200°C as widely



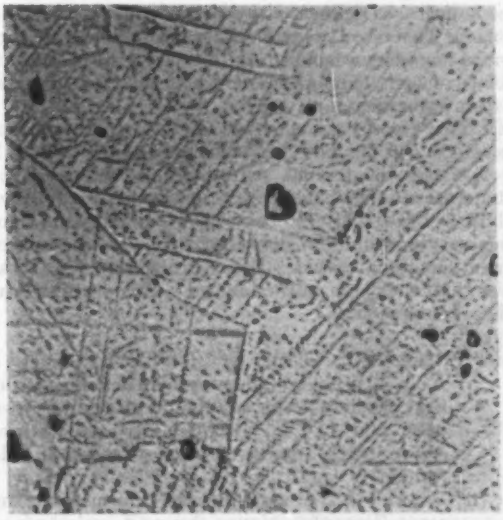
a *Solution treated 1050°C—1 h AC* ×600



c *Intergranular crack developed after 1% deformation during tensile test at 850°C, after solution treatment at 1350°C* ×600

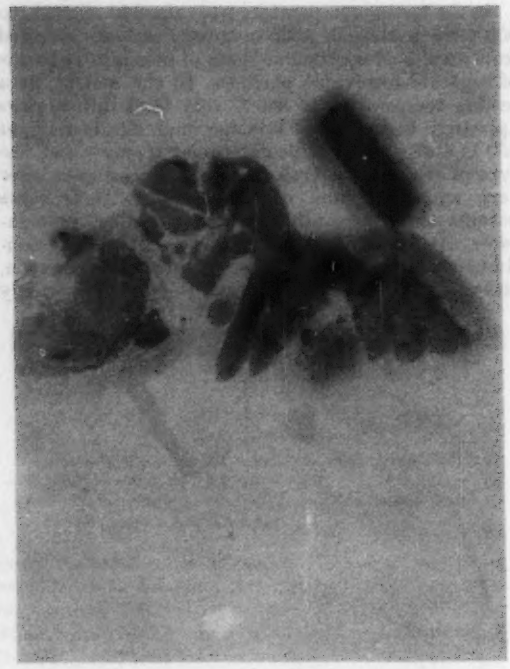


b *Solution treated 1050°C—1 h AC, and for 3 min at 1350°C, AC* ×600



d *Tensile tested at 1100°C after solution treatment at 1350°C* ×600

2 *Optical micrographs of 18–12–*Nb *austenitic stainless steel showing the effect of solution treatment and hot tensile testing*



3 *Grain boundary chromium carbide in specimen solution treated at 1050°C* ×60000

4 *Grain boundary chromium carbides in specimen tensile tested at 650°C after solution treatment at 1350°C* ×10000

spaced 'dot' type carbides. The matrix precipitates became more easily discernible as the testing temperature increased, until at 1100°C the rows were readily visible (*see* Fig.2*d*). At 1200°C, however, a more random type of matrix precipitation occurred and the volume of carbides present was somewhat less than at 1100°C.

The specimens tested at 1000°, 1050°, and 1100°C showed signs of a denuded zone near the grain boundaries, as delineated by lack of row-type precipitation. This effect was especially noticeable near large grain boundary carbides. At 1200°C there was no evidence of such denudation, very little row type precipitation being visible anywhere.

Effect of tensile testing after solution treatments and ageing at 850°C The specimens aged at 850°C for 3 h before tensile testing exhibited basically similar structures to the unaged tensile specimens, except that those tested at 700°, 750°, and 800°C showed some veining or sub-graining in the matrix. Also the amount of grain boundary carbides found at 850° and 900°C was less than that seen in the unaged specimens tested at these temperatures.

Conclusions drawn from the optical microscope survey

(i) A coarse grain boundary carbide developed during tensile testing at temperatures between 650° and 1200°C although at temperatures above 950°C there was less of this carbide formed.

(ii) Fine matrix precipitates were formed on the crystallographic planes during tensile testing between 800° and 1100°C. This was the temperature range over which the material exhibited reduced ductility.

(iii) Specimens aged for 3 h at 850°C before tensile testing, and which had good ductility values, contained grain boundary carbides, but the matrix did not give any indications of fine precipitation along crystallographic planes.

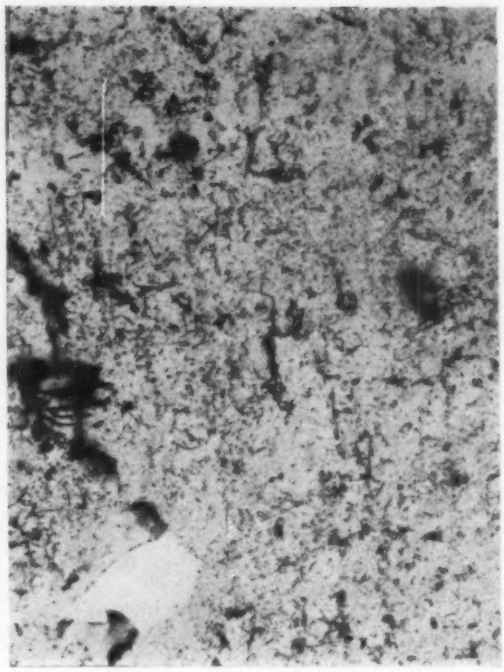
Structures shown by electron microscope

Effect of solution treatment The matrix of the specimen air cooled from 1050°C, after 1 h, was free from fine precipitation, but some 'dot' type carbides (1 μ) seen in the optical microscope had been extracted and replicas of the larger copper coloured niobium carbides (10–15 μ) were also present. At the grain boundaries (Fig.3) an irregular leafy chromium carbide of the $M_{23}C_6$ type was found. This was of the order of 0·2–0·5 μ long and its form suggested that it had formed on cooling from the solution treatment temperature.

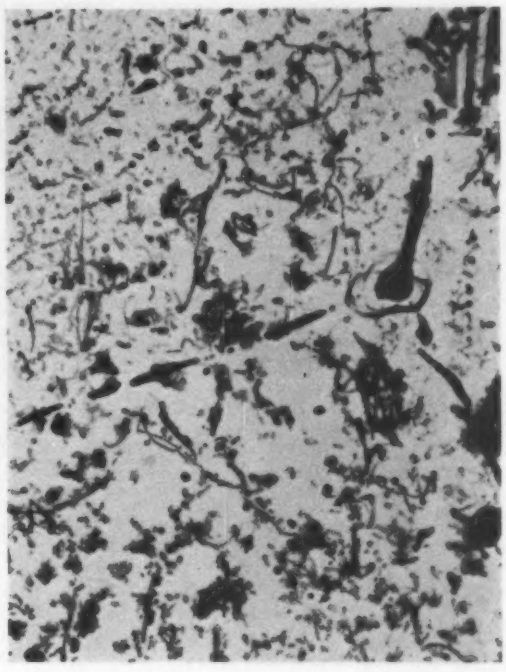
Solution treatment at 1350°C for 3 min resulted in the formation of larger and more numerous grain boundary carbides of the $M_{23}C_6$ type, with very short secondary limbs developed in a dendritic pattern. These carbides were about $\frac{1}{2}$ μ long but still very thin. No fine precipitates were seen in the matrix although replicas of the 'dot' type niobium carbides (1–2 μ) were present.

In the following notes the structures described relate to the specimens air-cooled from 1050° and 1350°C followed by hot tensile testing, the corresponding changes in ductility being as shown in Fig.1.

Structure after tensile testing at 650°C following solution treatment, elongation 26·5% During tensile testing some growth of the grain boundary carbides had occurred and the secondary arms were more pronounced (Fig.4). Apart from a few small cubes and



5 *Fine matrix niobium carbides and grain boundary $M_{23}C_6$ type carbide in specimen deformed 1% at 850°C after solution treatment at 1350°C* ×10000



6 *Fine matrix niobium carbides and grain boundary $M_{23}C_6$ type carbides in specimen deformed 1% at 850°C after solution treatment at 1350°C* ×60000

lath-shaped carbides the matrix was free from fine precipitation.

Structure after tensile testing at 850°C following solution treatment, elongation 6% At this testing temperature a specimen was examined after it had been deformed only 1%, i.e. while straining had taken place for a minute or so at temperature. As seen in the optical microscope such embrittlement had occurred that shallow intergranular cracks developed (Fig.2*c*).

The electron microscope revealed that the grain boundary carbides were mostly of the $M_{23}C_6$ type having developed the classical fernlike form, referred to by other workers[23–25] and shown in Figs.5 and 6.

In the matrix copious precipitation of niobium carbides had occurred both as fine threads on dislocations, 25–100 Å thick and up to 3000 Å long, and as discrete rectangular and cubic platelets up to 100 Å long.

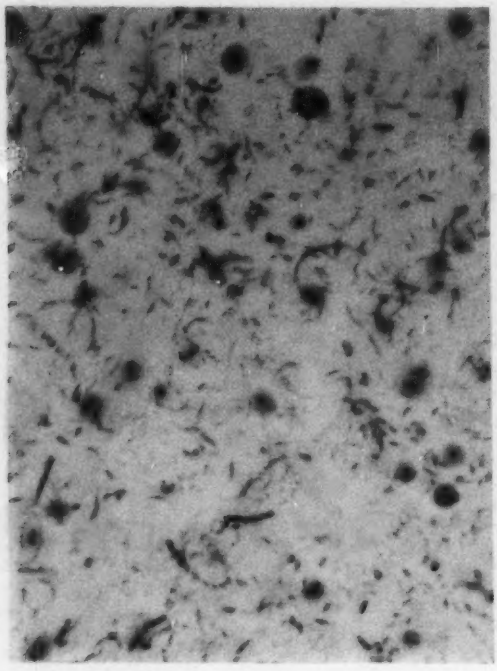
Preferential precipitation of these fine niobium carbides had occurred on the 111 planes of the austenitic lattice operative in the deformation process. In many grains it was possible to see this type of precipitation in three different directions (Fig.5). The matrix carbides were precipitated right up to the grain boundaries. Some large niobium carbides ($\frac{1}{2}\mu$) were extracted and corresponded to the 'dot' type carbides seen under the optical microscope. Around such carbides there was a higher concentration of fine niobium carbides of the dislocation thread type. This was probably caused as a result of lattice strains set up owing to the difference between the coefficients of thermal expansion of the matrix and the large niobium carbides[26] as illustrated by Arrowsmith.[27]

The specimen that was broken at 850°C was about 4 min at temperature and showed similar features to those seen in the specimen subjected to 1% strain. The matrix precipitates were slightly larger, however, and there were fewer fine discrete platelets present (Fig.7).

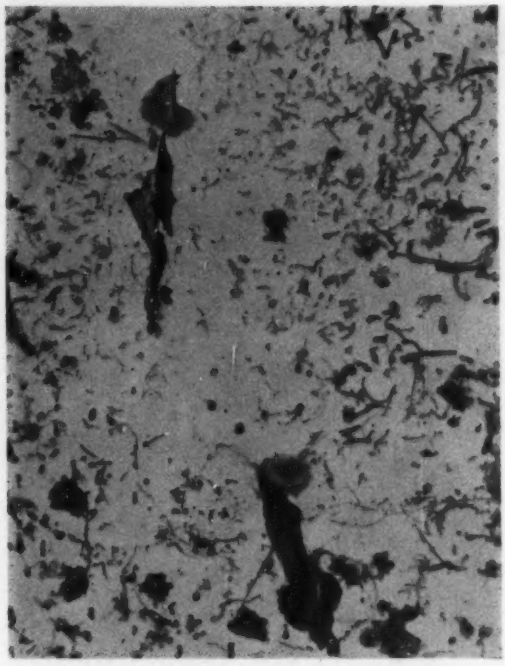
In both the specimen strained 1%, and that broken at 850°C, the density of dislocation thread-type niobium carbides was greatest near the grain boundaries (~ 2–6×10^6 cm^{-2}). Such concentrations of precipitates occurring after small strains would result in further deformation in the grain boundary regions being severely restricted and could lead to sufficient stress build-up at the grain boundaries to initiate intergranular fracture.

Structure after tensile testing at 950°C following solution treatment, elongation 10·5% This specimen exhibited all the general features seen in the specimens tested at 850°C but with some modifications. The grain boundary $M_{23}C_6$ type carbides were larger but had the characteristic leafy form (*see* Fig.9). The halo effect round the precipitate in this figure was produced by the abnormally thick carbon film necessary to extract these large carbides.

The matrix niobium carbides had nucleated on fewer sites and showed more extensive growth. There was also evidence that instead of precipitating in the matrix as niobium carbide, some carbon was diffusing to the grain boundaries and combining there with chromium. This was indicated by zones adjacent to the grain boundaries which were denuded of niobium carbide, as shown in Fig.8. In these zones it was found that the dislocation precipitates of niobium carbides



7 *Fine matrix niobium carbides of the dislocation thread type in specimen broken at 850 °C after solution treatment at 1350°C* ×60000



8 *Denuded zone at grain boundary in specimen tested at 950°C, after solution treatment at 1350°C* ×10000

associated with 111 slip planes in the austenite matrix tended to get smaller as the grain boundary was approached until the precipitate took the form of small discrete particles and then ceased some 0·7 μ from the boundary.

Structure after tensile testing at 1000° and 1050°C following solution treatment, elongation 8% and 7% respectively With further increase of testing temperature to 1000° and 1050°C the only changes in microstructure observed were an increase in size of the dislocation type niobium carbide precipitates, and precipitate separation, together with growth of the grain boundary carbides to about 2×4 μ. The denuded zone was between 1 μ and 3 μ wide. Figure 10 illustrates these features in a specimen tested at 1000°C. At high magnification this grain boundary carbide was seen to contain dislocations and what appeared to be slip bands.

Structure after tensile testing at 1100°C following solution treatment, elongation 3·5% At 1100°C considerable growth of the matrix carbides had occurred, these now tending to nucleate as separate cubes of niobium carbide along dislocations and slip planes, giving the impression of diffuse bands of precipitates (Fig.11). The presence of large $M_{23}C_6$ type carbides (Fig.12) was confirmed by electron micro-diffraction: Fig.13 shows the pattern obtained from the large well-developed fernlike carbide, inset at a magnification of ×6000. The '*d*' values calculated for this carbide are shown in Table II, together with the reported values for $Cr_{23}C_6$. These grain boundary carbides now measured 1–2 μ long and the denuded zone was about 2 μ wide in places. The matrix niobium carbides were between 200 Å and 900 Å square, while some large ($\frac{1}{2}$–1 μ) spherical niobium carbides were found at the grain boundaries.

Structure after tensile testing at 1200°C following solution treatment, elongation 9·5% The amount of matrix precipitation which occurred at this temperature was very small. Some dislocation type niobium carbides were present but the majority of the niobium was present as widely spaced overaged rectangular particles (Fig.14). The grain boundaries contained some large ($\frac{1}{2}$–1 μ) spherical replicas similar in shape and size to the niobium carbides observed in the specimen tested at 1100°C. Some $M_{23}C_6$ type carbides were seen at the grain boundaries as elongated envelopes and in a large triangular form.

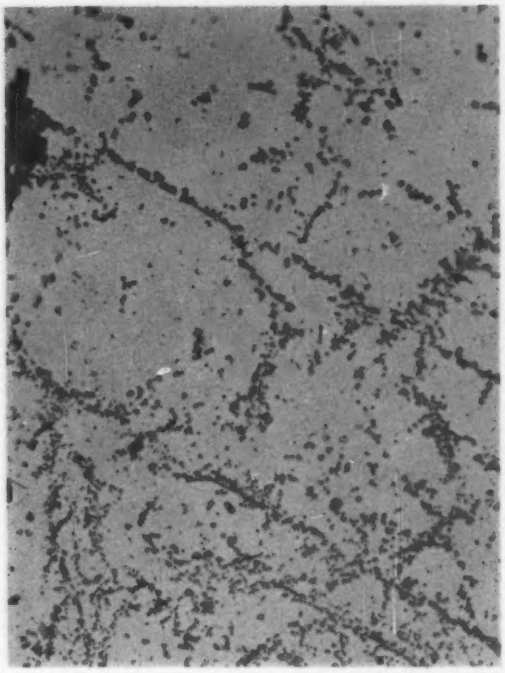
Effect of ageing at 850°C after solution treatment and before hot tensile testing Referring to Fig.1, it will be

TABLE II Electron micro-diffraction results for grain boundary carbides in 18–12–Nb steel

The following electron micro-diffraction results relate to the grain boundary carbide seen in a specimen tensile tested at 1100°C and shown as an insert on the diffraction pattern in Fig.12.

Observed '*d*' values (Å units)	Reported '*d*' values (Å units) $Cr_{23}C_6$	NbC
2·63	2·66	
2·53		2·54
2·07	2·05	
1·83	1·80	
1·69	1·68	
1·66	1·62	
1·56		1·55
1·51	1·49	
1·40	1·38	

9 *Large fernlike $M_{23}C_6$ type grain boundary carbide in specimen tested at 950°C after solution treatment at 1350°C*
×60000

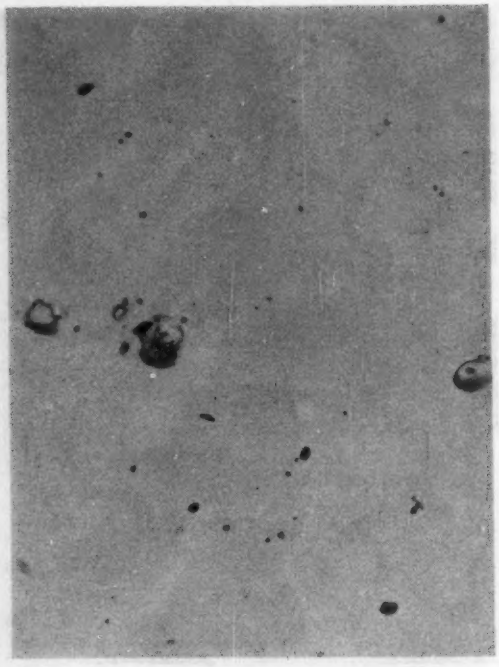


11 *Diffuse bands of niobium carbides on slip planes in specimen tested at 1100°C after solution treatment at 1350°C*
×60000

10 *Denuded zone around large grain boundary $M_{23}C_6$ type carbide together with fine matrix niobium carbides in specimen tested at 1000°C after solution treatment at 1350°C*
×10000

12 *Grain boundary $M_{23}C_6$ type carbides and denuded zone in specimen tested at 1100°C after solution treatment at 1350°C*
×10000

13 *Diffraction pattern from the grain boundary carbide shown, which was taken from the specimen tested at 1100°C after solution treatment at 1350°C* ×6000



14 *Widely distributed rectangular niobium carbides near grain boundary in specimen tested at 1200°C after solution treatment at 1350°C* ×10000

seen that pre-ageing for 3 h at 850°C without strain, following a solution treatment at 1350°C raised the ductility trough at 850°C from 6% to 22·5% elongation. Specimens were examined to account for this behaviour.

Specimens aged at 850°C for times of $\frac{1}{2}$, 1, and 3 h, without strain, did not show the dislocation thread type of niobium carbide precipitation in the matrix, which was characteristic of the specimens strained in the range 800–1050°C. Instead the niobium formed discrete spherical carbides whose size increased with ageing time from 100 Å after $\frac{1}{2}$ h to 200 Å after 3 h. Some of these precipitates, while separated from their neighbours by at least 200 Å, had nucleated on dislocations outlining a form of network or sub-grained structure (Fig.15). (A more marked example of this type of network has been seen in a steampipe which had been in service several thousands of hours.) There was a slight tendency for preferential precipitation on particular crystallographic planes, this being more prevalent near large (1–2 μ) matrix niobium carbides[25–27] of the type seen in the optical microscope. A grain boundary denuded zone was present, while the grain boundary carbides were mainly large spherical niobium carbides with some small ($\frac{1}{2}$ μ) leafy $M_{23}C_6$ type carbides.

When tensile tests were carried out in the range 700–850°C on the specmiens aged for 3 h at 850°C after solution treatment, the influence of strain on the form of the niobium carbides was again indicated by the appearance of fine dislocation thread type precipitates in the matrix; but the amount of thread type precipitate was naturally limited by the degree to which precipitation of spherical niobium carbide had occurred on ageing previously. Thread type niobium carbides were observed in the specimens tested at temperatures of 700–850°C. The structure of the 700°C specimen is shown in Fig.16 and that of the 900°C specimen in Fig.17. It will be seen that at 900°C most of the niobium carbide appeared as evenly distributed plates.

At the grain boundaries very coarse leafy $M_{23}C_6$ type carbides were found at 700°C as shown in Fig.16, but at higher temperatures (800°, 850°, and 900°C) these carbides were considerably smaller (1 μ). A denuded zone was still visible at 850°C.

*Microstructure of 17–11–*Mo *steel after tensile testing at 850°C* Specimens of an austenitic stainless steel containing molybdenum were examined after 3, 6, and 9% plastic deformation at 850°C, following solution treatment at 1350°C. These gave no indication of the dislocation thread type matrix precipitates seen in the niobium stabilized steel.

There were many large grain boundary carbides present of the $M_{23}C_6$ type, but the matrix contained only small amounts of fairly large (2500 Å long and 750 Å wide) lath-shaped chromium carbides of the Cr_7C_3 type.

SIGNIFICANCE OF MICROSTRUCTURE IN RELATION TO DUCTILITY ON HOT TENSILE TESTING OF 18–12–Nb STEEL

1. The grain boundary chromium carbides of the $M_{23}C_6$ type, which formed on cooling from 1350°C, were present in appreciable amounts after subsequent tensile testing at temperatures up to 1100°C.

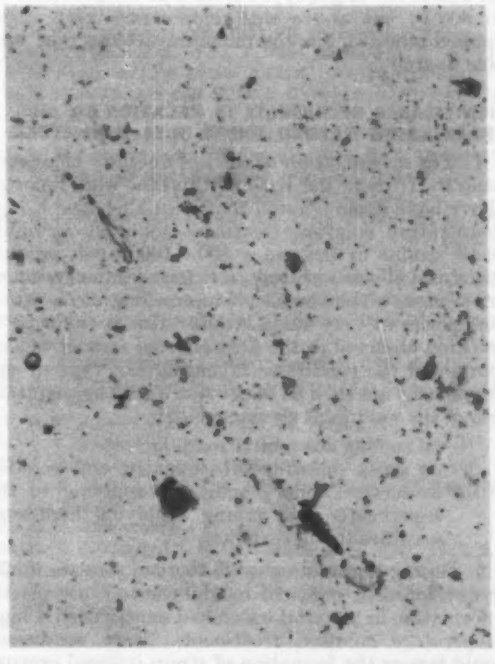
15 *Grain boundary replicas and 'discrete' precipitates of niobium carbide in specimen solution treated at 1350°C and aged at 850°C for 3 h without strain* ×10000

16 *Grain boundary $M_{23}C_6$ type carbides and fine dislocation thread type niobium carbides in specimen tested at 700°C after solution treatment at 1350°C and ageing at 850°C for 3 h* ×10000

2. While after solution treatment there was substantially no precipitate within the austenite grains, tensile testing in the region of 850°C subsequently brought about precipitation of niobium carbides. The fact that nucleation did not occur on simple cooling and that the precipitates had an entirely different form when precipitated during ageing at 850°C in the absence of strain, indicated that the dislocation thread type of niobium carbide precipitation seen after tensile testing was strain induced.

This structure with most of the available dislocations locked by niobium carbides, would tend to localize strain at the grain boundary regions wherein large two-dimensional $M_{23}C_6$ type carbides formed an almost continuous network (Fig.6). The result was that intergranular cracking had begun at only 1% deformation and fracture occurred with an overall elongation of 6%. Overageing of the niobium carbides which occurred at higher temperatures led, it is believed, to the slight recovery of ductility at 950°C.

3. In specimens tested at 950°C and above, the combination of carbon with chromium to form more $M_{23}C_6$ carbides along the grain boundaries, in preference to niobium carbide within the grains, resulted in the formation of the denuded zone adjacent to the grain boundaries. This denudation was very marked in specimens tested at 1050° and 1100°C and may have been the cause of the further loss of ductility shown on tensile testing in this temperature range. This is likely because it would tend further to increase the quantity of carbide at the boundary and because strain would tend to be localized in the weak denuded zone near the brittle boundary instead of being evenly distributed through the body of the crystals.



17 *Small grain boundary $M_{23}C_6$ type carbides and matrix niobium carbides in specimen tested at 900°C after solution treatment at 1350°C and ageing at 850°C for 3 h* ×10000

4. Between testing temperatures 1100–1200°C the niobium carbide in the matrix becomes widely dispersed as coarse particles owing to overageing. This is consistent with a reduced stiffening effect within the grains and with the improved ductility observed on testing at 1200°C.

5. The result of ageing test pieces for 3 h at 850°C before tensile testing was to precipitate niobium carbides in an even distribution of spherical particles. This restricted the amount of niobium and carbon available in solid solution for the formation of strain induced dislocation thread type niobium carbides during subsequent tensile tests. With fewer dislocations locked by niobium carbide precipitation the material possessed superior ductility. Curve *B*, Fig.1, showing the ductility of the aged hot tensile specimens is substantially different from curve *A* relating to unaged specimens.

6. At the grain boundaries there were $M_{23}C_6$ type carbides as in the unaged series. In the specimen tested at 700°C very coarse leafy carbides were found (Fig.16), whereas after testing at 800–900°C the carbides were smaller (1 μ).

7. It appears that the precipitation and growth of the grain boundary $M_{23}C_6$ type carbide is governed by strain and the degree of carbon supersaturation in the austenite. Fairly large $M_{23}C_6$ type carbides ($\frac{1}{2}$ μ long) were produced after air cooling from high solution treatment temperatures in the presence of strain resulting from thermal contraction. Whereas growth of these grain boundary carbides occurred, even at the expense of niobium carbide, at temperatures up to 1100°C under applied strain, very little detectable growth occurred during ageing for 3 h at 850°C. The application of strain to an aged structure caused rapid growth of the $M_{23}C_6$ type carbides at temperatures up to 800°C, but above this temperature even under applied strain it was the niobium carbides that were able to grow.

SIGNIFICANCE OF RESULTS IN RELATION TO CRACKING OF WELDED JOINTS IN 18–12–Nb STEEL

1. The investigation of the hot ductility characteristics by Truman and Kirkby[20] and the work reported above have demonstrated that with this steel a high temperature solution treatment followed by quite small strains in the range 800–1100°C can produce structural effects resulting in extreme intercrystalline brittleness, which can result in cracking at the grain boundaries at very small strains. This is the type of cracking observed in the heat-affected zone of welded joints and the conditions favouring this type of embrittlement are such as to provide a rational explanation of the weld joint cracking, either

(i) on cooling down after welding
(ii) on stress relieving subsequently, and possibly
(iii) in service under conditions applying to the superheater and piping supplying high-temperature steam turbines.

2. During the welding cycle thermal stresses would be developed of sufficient magnitude to cause plastic deformation in material which had experienced a high temperature solution treatment. These conditions would favour the formation of strain induced precipitation of dislocation thread niobium carbides and large grain boundary chromium carbides in the temperature range 800–1100°C. It has been shown that such a structure favoured intergranular cracking after very small amounts of plastic strain during hot tensile testing. Grain boundary denudation of niobium carbide might also contribute to the heat-affected zone cracking in welded components of this steel.

While on Truman and Kirkby's hot tensile tests brittleness was most pronounced on testing at 850° and 1100°C, similar effects occurring in the heat-affected zone might result in the development of a brittle structure which would persist on cooling down to lower temperatures. Cracking in the heat-affected zone of welds therefore need not be confined to the temperature range 850–1100°C and may occur at lower temperatures.

3. It has been shown by Truman and Kirkby that slow cooling after a high temperature solution treatment results in satisfactory ductility on hot-tensile testing subsequently. A fairly rapid cooling rate, as in a weldment, satisfied the conditions for producing low ductility levels by retaining the carbon and niobium in solid solution until they can be precipitated in the most damaging form.

4. Cracking in the heat-affected zone by the mechanism referred to above is likely to be extremely difficult to detect and it is not clear therefore whether cracking, found in welded joints after stress relieving, is initiated during stress relieving or not. In view of the structures observed, however, the initiation or propagation of cracks during stress relieving seems possible. On cooling down after welding, residual stresses of about yield point magnitude may exist and, in parts of the heat-affected zone at least, these must be in tension. With a non-uniform structure involving a brittle intergranular network of carbides and a matrix stiffened with locked dislocations, and perhaps bounded by narrow denuded zones, relaxation of these stresses may involve severe local plastic strains. This implies the possibility of cracks starting or of existing cracks propagating. Whether cracking occurs or not it is also possible for embrittlement, occuring during cooling after welding, to continue during stress relieving through further strain induced precipitation of niobium carbide within the crystals and $M_{23}C_6$ chromium carbide along the crystal boundaries.

5. If a part that has not been stress-relieved, such as a steampipe, is put into service at a high steam temperature the mechanism referred to above may operate in service and may lead to the development or spread of cracks in a period much less than the normal service life.

If it is assumed that a pipe butt weld, say, is completely sound after stress relieving, cracking of the type with which this investigation is concerned would not be expected to occur in service. Under these conditions, the life will be determined by the creep rupture characteristics of the material, taking microstructural effects in the weld and heat-affected zone into account, also the possibility of local creep life exhaustion due to differential strain effects as between grain boundary material, matrix material, and the carbide denuded zone sandwiched between.

6. A mechanism has been put forward to account for the cracking experienced in the heat-affected zone of many 18–12–Nb weld joints. There are, of course, many joints in service which have not failed and it has to be remembered that many factors such as weld

geometry, electrode composition, welding procedure, and weld restraint may also be involved. It may be that cracking is promoted only under a bad combination of such conditions. It would appear, however, that with very many joints it had been touch and go whether cracking occurred or not.

7. The structural effects that account for the variation in ductility on Truman and Kirkby's hot tensile tests and which it is suggested may explain also the cracking of 18–12–Nb steel on welding, do not suggest how this cracking can be avoided by any easy modification of the welding technique.

In order to be effective, preheat temperatures of 900–1000°C would be required and these of course would be impracticable. If it is held that cracking occurs on stress relieving rather than on cooling down after welding, then the risk of cracking might perhaps be reduced by not stress relieving in the region of 850°C. To ensure an adequate degree of stress relief this might mean stress relieving at 1000–1050°C. This again is difficult and does not avoid the risks involved in passing through the critical range of temperature twice, once on cooling after welding and again on reheating for stress relieving. In connexion with the latter risk, it is perhaps worth noting that for rather different reasons Curran and Rankin[11] have suggested a two-stage stress relieving treatment, at 600°C to reduce the major stresses somewhat followed by heating to 1050°C to complete the stress relieving process. A treatment of this type might have some advantage in limiting the amount of stiffening on heating through 850°C.

CONCLUSIONS

From the evidence presented above the following conclusions appear to be warranted.

1. The marked changes in the ductility of 18–12–Nb steel, as found by Truman and Kirkby on hot tensile tests at temperatures between 650° and 1200°C after a previous treatment at 1350°C, are attributable to changes in microstructure. The effect of ageing at 850°C after the high temperature treatment and before hot tensile testing is also accounted for on the same basis.

2. The microstructural changes which govern the ductility on hot tensile testing are:

(i) grain coarsening at 1350°C

(ii) the precipitation of a network of chromium carbides of the $M_{23}C_6$ type at the grain boundaries

(iii) precipitation of niobium carbide as discrete particles within the crystals in the absence of plastic strain

(iv) precipitation of niobium carbide within the crystals in a thread-like form on dislocations associated with the 111 slip planes. This is a strain induced effect which can occur at temperatures in the region of 850°C in the presence of a strain below 0·01 and which appears to have a marked stiffening effect due to dislocation locking

(v) the combination of carbon with chromium to form more grain boundary carbide in preference to niobium carbide within the grains, thus giving rise to denuded zones adjacent to the grain boundaries.

The way in which these structural changes correlate with ductility has been indicated.

3. The conditions under which the above mentioned structural changes occur and the way in which they influence the hot ductility of the metal suggest strongly that similar metallographic changes occur in the heat-affected zone of welded joints and may reduce the ductility so much as to permit cracking under the influence of contraction stresses, either on cooling down after welding, on stress relieving, or possibly in service.

4. Comparative tests by Truman and Kirkby on a steel of the 17–11–Mo type did not develop low ductility on hot tensile testing and did not show the structural effects found to be characteristic of 18–12–Nb steel in the brittle condition.

ACKNOWLEDGMENTS

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Some effects of heat-treatment upon the impact-fatigue life of Ni-hard grinding balls

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SYNOPSIS

The effects of heat-treatment on the life to fracture, under conditions of repeated impact, of the nickel–chromium alloy white cast iron Ni-hard, *have been investigated. The improvements in life obtained were found to be related to changes observed in the microstructure of the primary phase, and a theory is put forward to explain the various results obtained.*

A field test of grinding balls, subjected to the preferred heat-treatment developed indicated that the alloy iron had much superior wear resistance to that of forged medium carbon steel, and no difficulties were experienced due to ball breakage over a test period of 14 months. 1910

INTRODUCTION

NI-HARD, a white cast iron containing 4½%Ni and 1½%Cr, has a well-established position in industry as an abrasion-resistant material.[1] It combines exceptional hardness, wear-resistance, and moderate toughness with good founding properties.[2] Ni-hard is usually employed in conditions of dry or wet abrasion, e.g. for grinding-mill liners, sand mullers, etc.[3, 4] for which its outstanding resistance to abrasion make it particularly suitable. While in many such applications a considerable amount of repeated impact is involved (e.g. in ball- and rod-mill liners), the service stresses in such cases are of a low order, and it has been found that Ni-hard has ample toughness to withstand them.[5] However, under very heavy repeated impact, such as is encountered by balls in a large-diameter ball mill (10–12 ft dia.) breakage of Ni-hard balls may occasionally occur. It is most often met with in balls of iron which are 'off-composition', or in unsound balls, but it has been observed that under extreme conditions, where both mill and ball are of large diameter, fracture may occur even in Ni-hard of fully satisfactory metallurgical quality. The need therefore arose to increase the toughness of this type of iron without seriously impairing its excellent abrasion-resisting qualities.

Examination of the microstructure of typical as-cast Ni-hard shows that three main phases are present (Fig.1). The structure consists of primary dendrites of austenite, which have subsequently been partly transformed to martensite on cooling, in a matrix of eutectic carbide. A typical composition for, say, a 60-mm dia. grinding ball would be

%C	%Si	%Mn	%S	%P	%Ni	%Cr
3·0	0·4	0·6	0·06	0·04	4·0	2·0

Examination by both the Castaing micro-probe analyser and the carbide-extraction techniques has shown that the alloying elements are unequally divided between the phases found in the microstructure. The chromium parts almost exclusively to the carbide, while the nickel is concentrated in the austenite–martensite dendrites. The function of the chromium is to increase the hardness of the Fe_3C phase (900–1200 DPN), while the nickel exerts its well known effect upon the hardenability of the primary phase. The Ni-hard composition is balanced so that the graphitizing effects of elements such as silicon and nickel are completely offset by the carbide-stabilizers manganese and chromium. No graphite should be present, and a normal structure would have about 50% of martensite in the austenite dendrites, in a matrix of eutectic carbide.

In correlating microstructure with incidence of cracking under conditions of severe impact, it was found that cracks always tended to follow the path of the carbide network, seldom, if ever, cutting through austenite–martensite aggregates.

It was also found that if the surface layers of Ni-hard balls are subjected to repeated heavy impact, deformation of the unstable austenite phase will cause it to transform to martensite, and the resulting expansion builds up high compressive stresses in the surface layers. This compressive stress at the surface results in the central area of the ball being subjected to high tensile stresses, which build up until the stress level is such that one more blow contributes sufficient additional stress to cause central failure because the cohesive strength of the material is exceeded. This mechanism of breakdown has been confirmed to some extent by practical observations of ball failure.

Under conditions of repeated relatively light impact there is a tendency for a very thin surface layer to be deformed and this can result in spalling of surface layers. Intermediate conditions of repeated impact have often been found to result in cap fracture.

The observations made indicated several potentially useful lines of work:

(i) production of a discontinuous carbide structure
(ii) toughening of the carbide phase

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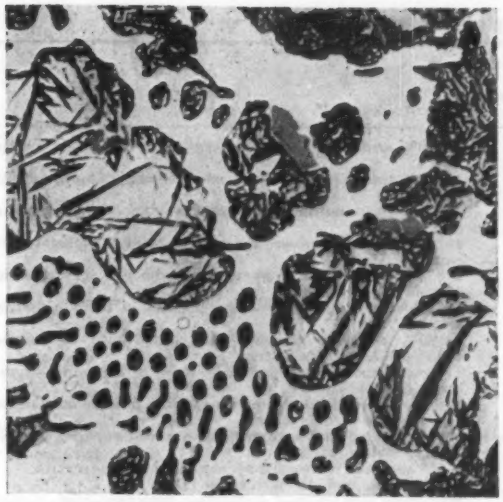


1 *As-cast microstructure of a 1½-in dia. grinding ball* ×1000

(iii) toughening and stabilizing of the austenite–martensite dendrites

(iv) refining the distribution of both phases.

All these lines of investigation have been followed up: the present paper is concerned with work done under section (iii).

While several previous investigators[6–9] have studied the heat-treatment of Ni-hard, no qualitative assessment has been made of the effects of such treatments on impact-fatigue life.

Although, at first sight, it would appear that changes in the austenite–martensite support phase might have only small effects upon the toughness of the balls when subjected to repeated heavy impact, preliminary tests of a rudimentary nature soon indicated that this presumption was not justified. This finding led to the start of a comprehensive investigation.

Apparatus was constructed in which balls can be subjected to impact conditions resembling those obtaining in a ball mill (Fig.2) and, with this machine, tests were made to ascertain the extent to which the impact-resistance of a batch of commercial Ni-hard balls can be improved by heat-treatment.

MATERIALS TESTED

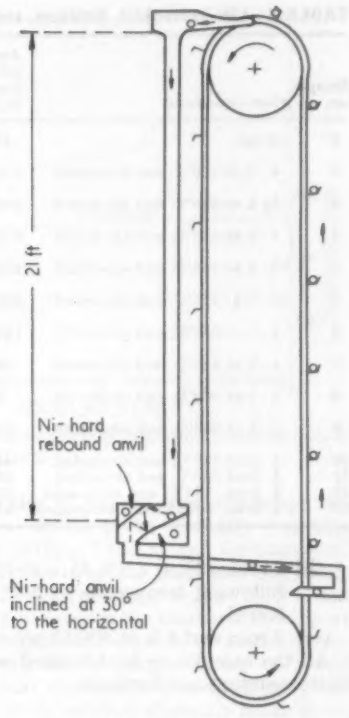
The balls chosen for investigation were of 1½ in dia., and were cast in greensand moulds from one heat of iron made by a commercial foundry. They had the following composition

%C	%Si	%Mn	%S	%P	%Ni	%Cr	%Mo	%Cu
3·39	0·63	0·60	0·089	0·052	3·51	1·40	0·01	ca0·02

The as-cast microstructure consisted of martensite 50–60% austenite aggregates in a matrix of carbide (Fig.1), and only a small percentage of the balls was found to suffer from porosity or to contain flake graphite. The hardness of the as-cast balls was 715 DPN.

EXPERIMENTAL PROCEDURE

In the test apparatus the grinding balls were repeatedly caused to fall from a height of 21 ft on to an inclined Ni-hard anvil (Fig.2). The number of impacts necessary to cause fracture was determined, for balls in the



2 *Diagrammatic sketch of the ball-testing apparatus*

as-cast condition, and for balls which had undergone one or other of the following heat-treatments:

1. 4 h at 200°C
2. 1½ h at 275°C
3. 4 h at 275°C
4. 36 h at 275°C
5. 48 h at 275°C
6. 4 h at 350°C
7. 4 h at 450°C
8. 4 h at 500°C
9. 4 h at 550°C
10. 4 h at 750°C
11. 4 h at 850°C

(1–11: air-cooled)

12. 4 h at −78°C, air-heated to room temp.
13. 4 h at −196°C, air-heated to room temp.
14. 4 h at 150°C
15. 4 h at 275°C
16. 4 h at 350°C
17. 4 h at 450°C
18. 4 h at 550°C
19. 4 h at 750°C
20. 4 h at 850°C

(14–20: air-cooled + 4 h at 275°C, air-cooled)

21. 4 h at −78°C
22. 4 h at −196°C

(21–22: air-heated to room-temp. + 4 h at 275°C)

At least four balls were subjected to each heat-treatment.

The fractured balls were sectioned for micro-examination and hardness determination. Immediately after fracture, the fractured surface of each ball was examined under a low-power binocular microscope, to determine its soundness and freedom from stress-concentrators such as surface defects.

Additionally, small pieces from as-cast fractured balls were heat-treated as indicated below, with a view to following more closely the constitutional changes liable to occur under various conditions:

(i) 4 min, 2, 4, and 48 h at 275°C; air-cooled

TABLE I Life-to-fracture, hardness, and microstructure after single heat-treatments

Sample no.	Heat-treatment	Average life-to-fracture, in drops	Mean variation, %	Hardness, DPN	Microstructure
0	As-cast	487	+10, −10	715	50–60% austenite martensite aggregates in carbide matrix (Fig.1)
1	4 h at 200°C, and air-cooled	1550	+10, −9	700	50–60% austenite tempered-martensite aggregates in carbide matrix
2	1½ h at 275°C, and air-cooled	2600	+7, −7	710	40–50% austenite tempered-martensite bainite aggregates in carbide matrix
3	4 h at 275°C, and air-cooled	3070	+10, −9	750	10% austenite tempered-martensite bainite aggregates in carbide matrix
4	36 h at 275°C, and air-cooled	4025	+7, −8	760	2–5% austenite tempered-martensite bainite aggregates in carbide matrix
5	48 h at 275°C, and air-cooled	4350	...	770	Tempered-martensite bainite aggregates in carbide matrix (Fig.8)
6	4 h at 350°C, and air-cooled	1065	+13, −17	700	50–60% austenite tempered-martensite trace of bainite aggregates in carbide matrix
7	4 h at 450°C, and air-cooled	266	±0	650	Tempered-martensite martensite trace of austenite aggregates in carbide matrix
8	4 h at 500°C, and air-cooled	90	+14, −14	625	10% austenite tempered-martensite fine pearlite martensite aggregates in carbide matrix
9	4 h at 550°C, and air-cooled	265	+12, −7	580	2% austenite tempered-martensite pearlite aggregates in carbide matrix (Fig.10)
10	4 h at 750°C, and air-cooled	442	+19, −11	760	2–5% austenite martensite aggregates in carbide matrix
11	4 h at 850°C, and air-cooled	295	+10, −14	800	Martensite in carbide matrix (Fig.11)
12	4 h at −78°C, and air-heated	355	+2, −2	780	Martensite with traces of austenite in carbide matrix
13	4 h at −196°C, and air-heated	370	+8, −5	790	Martensite with traces of austenite in carbide matrix (Fig.9)

(ii) 15 min, 2½, 4, 7, 16, 48, and 100 h at each of the following temperatures, 350°, 400°, 450°, and 550°C

(iii) 2 min and 4 h at 500°C; air-cooled.

All the samples so heat-treated were examined for microstructure and hardness.

EXPERIMENTAL RESULTS

The results of the drop tests are summarized in Tables I and II, and Figs.3–5. Each life-to-fracture figure quoted is the mean of at least four tests, and the percentage variation from the mean value is also given, to indicate reproducibility. Results obtained on balls found to be porous or to suffer from surface defects were discounted, and the tests were repeated.

It is believed that discussion of the effect of heat-treatment on impact-fatigue life will be made more comprehensible by prior presentation of an approximate isothermal-transformation diagram for the materials under consideration. Although this type of diagram may be used to indicate the transformations which occur in these irons, it must be remembered that we are here concerned with the reheating of a cast material which has first been cooled to room temperature and not with the isothermal transformation of an iron which has not passed its M_s temperature. The curves in Fig.6 illustrate onset of transformation throughout the temperature-range investigated. The diagram has been split up into five zones.

Zone A Isothermal transformation does not occur within a reasonable time, but martensite is tempered and carbide is precipitated from residual austenite, thereby raising its M_s temperature. Subsequent cooling therefore causes the formation of additional martensite.

Zone B Isothermal transformation of residual austenite to pearlite. Martensite is tempered.

Zone C As Zone A.

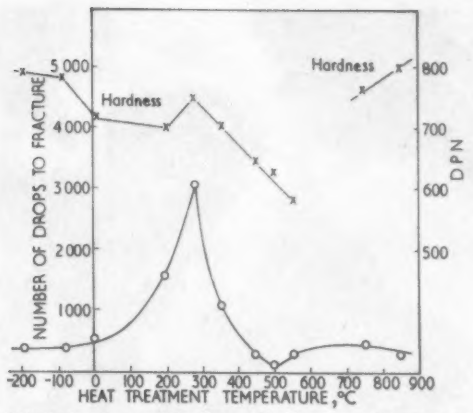
Zone D Isothermal transformation of residual austenite to bainite. Martensite is tempered.

Zone E There is a tendency to transformation of residual austenite to martensite above or below room temperature. If this occurs above room-temperature

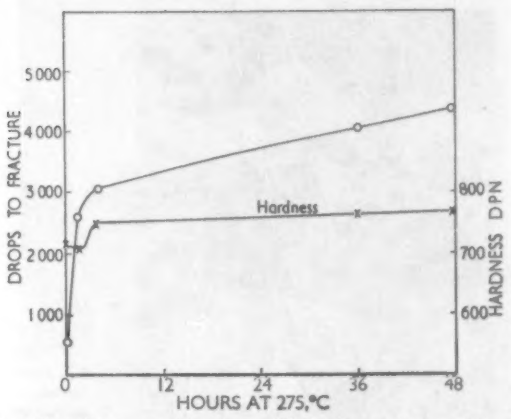
TABLE II Life-to-fracture, hardness, and microstructure after duplex heat-treatments

Sample no.	Heat-treatment	Average life-to-fracture, in drops	Mean variation, %	Hardness, DPN	Microstructure
14	4 h at 150°C, and air-cooled 4 h at 275°C, and air-cooled	1550	+1, −1	815	10–20% austenite tempered-martensite bainite aggregates in carbide matrix
15	4 h at 275°C, and air-cooled 4 h at 275°C, and air-cooled	945	+5, −5	800	10% austenite tempered-martensite bainite aggregates in carbide matrix
16	4 h at 350°C, and air-cooled 4 h at 275°C, and air-cooled	204	+4, −9	700	20–30% austenite tempered-martensite bainite aggregates in carbide matrix
17	4 h at 450°C, and air-cooled 4 h at 275°C, and air-cooled	7200	+2, −1	670	Tempered-martensite bainite in a carbide matrix (Fig.13)
18	4 h at 550°C, and air-cooled 4 h at 275°C, and air-cooled	455	+6, −4	595	Tempered-martensite pearlite trace of bainite aggregates in carbide matrix
19	4 h at 750°C, and air-cooled 4 h at 275°C, and air-cooled	5650	+20, −10	790	Tempered-martensite +2–5% bainite aggregates in carbide matrix
20	4 h at 850°C, and air-cooled 4 h at 275°C, and air-cooled	1076*	+22, −10	787	Tempered-martensite in carbide matrix (Fig.14)
21	4 h at −78°C, and air-heated 4 h at 275°C, and air-cooled	5570	+5, −20	780	Tempered-martensite with traces of bainite in carbide matrix
22	4 h at −196°C, and air-heated 4 h at 275°C, and air-cooled	5080	+12, −14	820	Tempered-martensite with traces of bainite in carbide matrix (Fig.12)

* Intergranular oxide penetration



3 *Life-to-fracture and hardness of balls after a 4 h single-stage heat-treatment*



5 *Life-to-fracture and hardness of balls after various periods of heat-treatment at 275°C*

some stress-relief is effected, but at sub-zero temperatures this effect does not occur.

Results obtained by means of a single-stage heat-treatment

Life-to-fracture

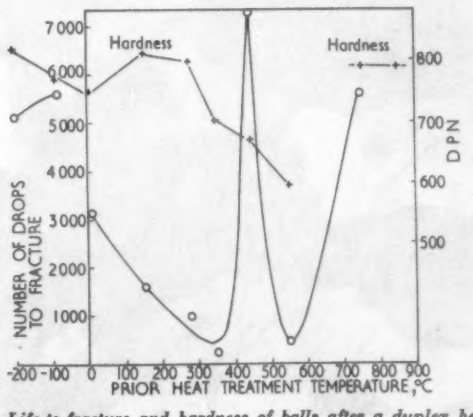
Considerable lengthening of life-to-fracture of a grinding ball may be obtained by heat-treatment in the region of 275°C (Table I). Treatment at substantially lower or higher temperatures did not effect the same degree of improvement (Fig.3). The standard time of heat-treatment was originally fixed arbitrarily at 4 h, but in view of the success of the treatment at 275°C, the time factor was varied for that temperature, and it was found that prolonging the period to 48 h produced a further large increase in life-to-fracture (Fig.5).

Microstructure

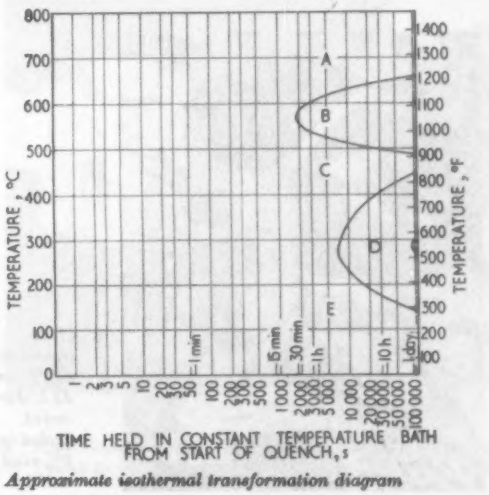
The microstructure of an as-cast ball is shown in Fig.1: the constituents present are 60% martensite–austenite aggregate in a matrix of carbide, the amount of residual austenite being 50–60% of the total aggregate area. Micro-examination, both before and after testing, of the balls which had been heat-treated (*see* Figs.7–11) indicated that at 275°C decomposition of the residual austenite to bainite was occurring: this transformation was found to be virtually complete after soaking for 48 h (Figs.7 and 8), and simultaneously the original martensite in the balls was tempered. Heat-treatment at temperatures below 275°C, say 200°C, served only to temper the martensite, without bringing about a significant amount of austenite decomposition. At still lower temperatures, −78 and −196°C, the original martensite was apparently unaffected but most of the residual austenite broke down to martensite (Fig.9). Heat-treatment at 350°C tempered the original martensite and brought about a slight transformation of the residual austenite to upper bainite. At 450°C, also, the original martensite was tempered but the residual austenite was found to have broken down almost entirely to martensite on cooling.

Heat-treatment at 550°C tempered the original martensite and caused transformation of most of the residual austenite to dark-etching fine pearlite, (Fig.10). Raising the heat-treatment temperature to 750°C or above resulted in virtually complete transformation of austenite to martensite on cooling (Fig.11).

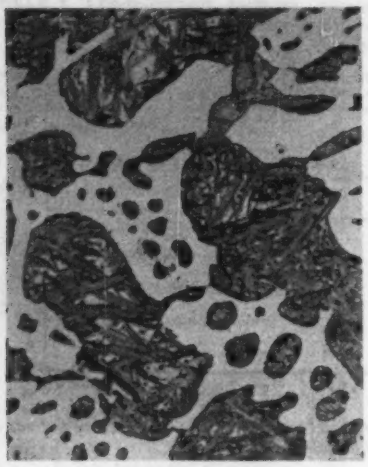
The variations in hardness of the balls were found to



4 *Life-to-fracture and hardness of balls after a duplex heat-treatment. 4 h at temperature indicated on scale, followed by 4 h at 275°C*



6 *Approximate isothermal transformation diagram*



7 *Heat-treated at 275°C for 4 h. Air-cooled. Etched in 2% nital* ×150

9 *Cooled to −78°C for 4 h. Air-heated. Etched in 2% nital* ×1000

be compatible with the microstructural changes (Fig.3). Sub-zero treatment raised the hardness, owing to the development of more untempered martensite: treatment at 200°C resulted in a slight fall in hardness, due to the tempering of the original martensite, without significant change in the amount of residual austenite. The optimum heat-treatment, at 275°C, was found to cause slight increase in hardness: formation of bainite from soft austenite tended to offset the loss of hardness associated with the tempering of the original martensite. Tempering at 350°C resulted in a slight drop in hardness, due to tempering of the original martensite without any substantial transformation of the austenite. The 450°C treatment which resulted in a mixed structure of martensite and tempered martensite, also produced a softer ball. The tempering of the original martensite, together with the decomposition of austenite to low-carbon martensite, did not cause any irregularity on the hardness curve (Fig.3). Heat-treatment at 550°C was associated with a further drop in hardness, consequent upon the appearance, in the microstructure, of a large amount of fine pearlite.

Treatment at 750°C and above produced a distinct rise in hardness, due to the development by this 'conditioning' heat-treatment of additional quantities of untempered martensite on cooling.

Microhardness tests on the carbide phase of balls after single heat-treatments indicated that while the general level of carbide hardness was 1150–1200 DPN, the hardness of the carbide after heat-treatment at 450°C was always in the range 1000–1100 DPN.

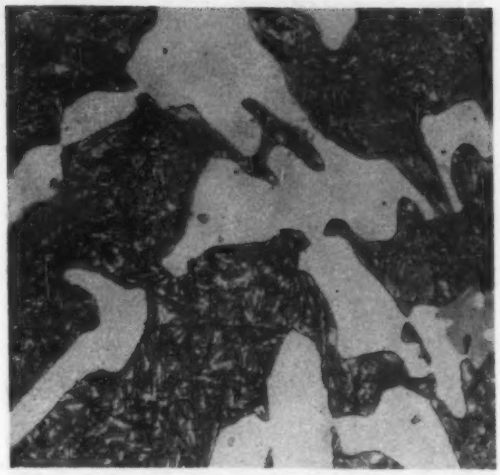
Results obtained by means of a duplex heat-treatment

Life-to-fracture

Table II and Figs.12–14 summarize the results obtained on balls subjected to a two-stage heat-treatment. Figure 4 demonstrates that three different types of treatment were effective in producing balls which had good drop-test lives: (i) a sub-zero treatment, followed by tempering at 275°C, (ii) a super-critical treatment followed by tempering at 275°C, and (iii) a low-temperature soak without intermediate-product formation, followed by tempering at 275°C. All three treatments result in virtual elimination of austenite without formation of pearlite, and in tempering of any

8 *Heat-treated at 275°C for 48 h. Air-cooled. Etched in 2% nital* ×150

10 *Heat-treated at 550°C for 4 h. Air-cooled. Etched in 2% nital* ×1000



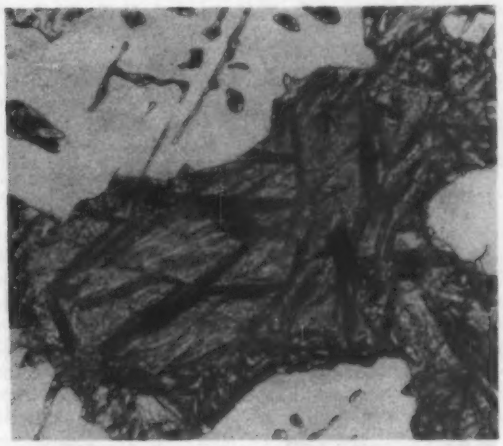
11 *Heat-treated at 750°C for 4 h. Air-cooled. Etched in 2% nital* ×1000

martensite formed during or subsequent to the first stage of the duplex heat-treatment.

Microstructure

The balls which were subjected to a sub-zero treatment followed by tempering at 275°C exhibited the types of structure illustrated in Figs.12–14. It was found that the martensite formed during the first stage of the treatment was tempered by the 275°C treatment, which would also tend to convert the last traces of austenite to bainite.

The balls which were given a prior super-critical heat-treatment followed by tempering at 275°C also showed final structures consisting of tempered martensite in a carbide matrix. Figure 4 indicates that the most effective treatment in the duplex series was one involving 4 h at 450°C followed by tempering at 275°C. The microstructure of a ball so treated is shown in Fig.13: it consists of a tempered martensite–bainite aggregate in a matrix of carbide.



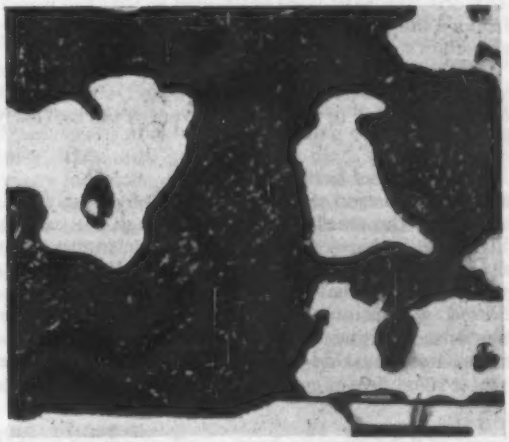
13 *Heat-treated for 4 h at 450°C+4 h at 275°C. Air-cooled. Etched in 2% nital* ×1000

Figure 4 also illustrates the variations in hardness produced by the respective heat-treatments. The wholly-tempered martensite structures resulting from prior sub-zero or super-critical treatments have a combination of high hardness and good impact-fatigue life, the balls giving optimum impact-fatigue life have slightly lower hardness. The hardness curve also demonstrates the soft nature of the transformation product resulting from heating at 550°C, and it is noteworthy that although this treatment produced the softest ball of the series, the impact fatigue life obtained was very poor.

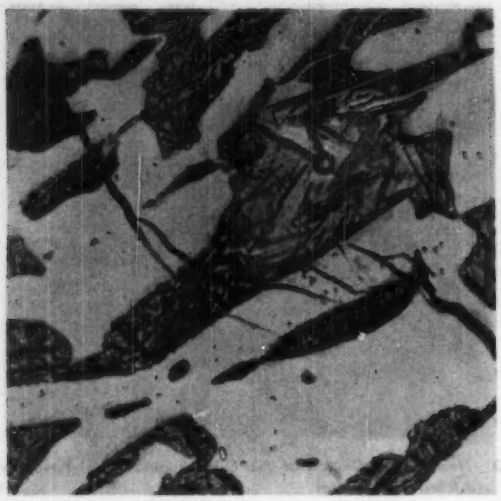
Results obtained in isothermal transformation tests

Isothermal transformation tests, carried out to clarify the transformation characteristics of this batch of Ni-hard, indicated that the bainite nose of the curve probably occurred at about 275°C and that at about 550°C the onset of transformation to fine pearlite occurred after about 30 min. At 350°C transformation to upper bainite began only after soaking periods of

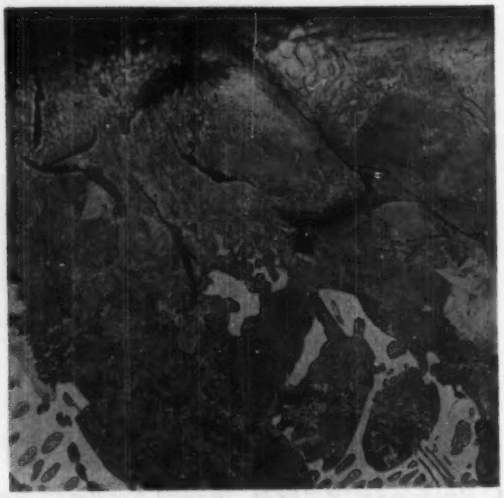
12 *Cooled to −196°C for 4 h. Heated 4 h at 275°C. Air-cooled. Etched in 2% nital* ×1000



14 *Heat-treated for 4 h at 850°C+4 h at 275°C. Air-cooled. Etched in 2% nital* ×1000



15 *As-cast Ni-hard, showing cracks through the carbide. Etched in 2% nital* ×1000



16 *Flake graphite and decarburized band at the surface of the Ni-hard ball. Etched in 2% nital* ×1000

more than 7 h, and at 450°C no intermediate product was precipitated, but, on cooling, the austenite did break down to light-etching martensite. Figure 6, which illustrates the type of S curve which the transformations observed would follow, does not purport to be an accurate picture, but it illustrates the broad effects observed in the various temperature ranges investigated.

Other factors which influence the life-to-fracture of a grinding ball

Soundness

From time to time balls showing varying degrees of unsoundness were encountered, and these invariably had lower drop-test lives than corresponding sound balls. Tests of behaviour under a single very heavy blow, made by dropping a weight of 2 cwt from a height of 13 ft, showed that if the blow was on to the ingate, unsound balls invariably fractured, but that if similarly unsound balls were positioned so that the weight dropped on an area at 90° to the ingate they usually withstood several blows before fracture.

Occasionally unsoundness took the form of subcutaneous blow-holes and, as expected, such defects led to exfoliation of the surface layers of the ball early in the test cycle.

Carbide-form and hardness

Micro-examination of fractured balls consistently indicated that the cracks propagate through the carbide (Fig.15): it is therefore probable that continuity of the carbide is an important factor, having a direct bearing on ball-life. The balls examined in this investigation showed a continuous to semi-continuous carbidic structure, and it would be expected that balls having a discontinuous carbide structure would have shown greater toughness as gauged by the life-to-fracture test.

Graphite

Traces of flake graphite have an effect similar to that of unsoundness. Graphite, when present, was found to occur in two positions in the balls: (*a*) at the surface (Fig.16), and (*b*) in the central areas, where it was often found to be associated with unsoundness and inclusions. In both positions it is, of course, undesirable, in the former case particularly so, since graphite in that region led to premature cap fracture.

It was observed that as the toughness of the balls was increased by the various heat-treatments applied the influence of surface flake graphite increased.

Surface oxidation

Heat-treatment at temperatures of 750°C or above, in an oxidizing atmosphere, was found to cause a type of intergranular oxide penetration (Fig.17): this also promotes premature cap fractures, in a manner similar to that observed for surface flake graphite.

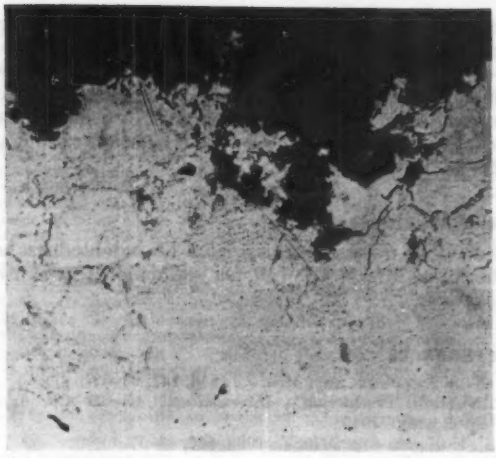
CONSIDERATION OF EXPERIMENTAL RESULTS

The best life-to-fracture in Ni-hard grinding balls appears obtainable by means of heat-treatments which break down residual austenite and promote tempered martensite and/or bainite. Increasing the amount of tempered martensite, at the expense of bainite, brings about a further improvement. The mechanisms by which these structures are produced by the heat-treatments described in the present work have already been discussed and illustrated with reference to the schematic isothermal-transformation diagram (Fig.6).

The structure formed by transformation in Zone D gives the longest life-to-fracture, as evaluated by the drop test described.

The duplex heat-treatments comprise simply the tempering, at 275°C, of structures produced by the single-stage treatments. Best results are given by structures consisting solely of tempered martensite and bainite (in the usual carbide matrix). The amount of martensite is increased by treating in Zones A, C, or E so that by subsequent tempering, high impact-resistance is obtained.

The duplex heat-treatment at 275°C with intermediate air-cool did, however, produce balls with an unexpectedly low impact-fatigue life (Table II). Although this result was carefully checked, very



17 *Oxide penetration into surface of* Ni-hard *after heat-treatment at 850°C under oxidizing conditions. Etched in 2% nital* ×1000

similar values for impact-fatigue life were obtained. A completely satisfactory explanation of this result has not yet been formulated but it is thought to be possible that when using two consecutive heat-treatments of 4 h at 275°C, the residual austenite which is present after these treatments is so conditioned, by fine carbide precipitation, that on subsequent cooling, untempered martensite is formed from it, shorter times at 275°C being insufficient to condition the austenite, while longer times completely transform residual austenite to bainite. It is therefore preferable, if using a 275°C heat-treatment, to hold isothermally at this temperature until all the austenite is completely transformed.

It has been shown that the presence of either very hard constituents such as untempered martensite, or of soft constituents such as pearlite, gives balls having poor impact-fatigue properties. It may well be that the basic carbide network requires the support of phases with certain definite elastic properties if it is to withstand repeated impact, and it is possible that constituents such as tempered martensite and/or bainite, which have intermediate properties, about fulfill these requirements. However, when failure *does* occur, the path of fracture invariably follows the brittle cementite network, and it thus appears probable that although the impact-fatigue life of Ni-hard may be considerably improved by modification of the non-carbidic portions of the structure, additional increase in life would be obtainable if the carbide could be modified, for example, to form a discontinuous network or a globular dispersion. It is considered to be also of some significance that heat-treatment at 450°C causes a definite drop in carbide hardness. This change may be accompanied by toughening of the carbide and it is thought possible that the drop in hardness may be due to precipitation of a sub-carbide. However, this hypothesis has not yet been confirmed.

Other investigators,[9] using X-ray and electron microscopical techniques, have also found that in irons of this type, tempering at 400°F (204°C) for 4 h causes precipitation of lamellar epsilon carbide in the martensite phase. This phenomenon was not investigated in the present work, but since it would be expected to exert a considerable influence upon the elastic properties of the support phase (the primary phase), it would probably have an important effect upon toughness under conditions of repeated impact. Reference to Fig.3 indicates quite clearly that a 200°C tempering treatment did in fact cause a very significant improvement in impact-fatigue life and some evidence was obtained of precipitation of a phase in martensite tempered at 275°C.

TABLE III Field test on 2½-in dia. double-heat-treated grinding balls in nickel-oxide sinter-grinding mill

Duration of test	14 months
Total weight of nickel-oxide sinter ground	42 000 short tons
Loss in weight:	
Ni-hard balls	0·12 lb/short ton of sinter ground
Forged medium-carbon steel balls	1·80 lb/short ton of sinter ground
Wear factor in favour of Ni-hard	15 to 1

The effects of heat-treatment on the single-blow impact strength of Ni-hard were determined also upon a separate heat of iron. Sand cast 0·798-in dia. bars were tested in a 120 ft/lb Izod apparatus. In these tests the as-cast balls proved to be the toughest, and the double-heat-treated balls were among the weakest. This result was entirely as expected, since the presence of austenite in the as-cast microstructure would have an important beneficial effect upon single-blow impact strength.

Single-blow impact tests were made also on 2½-in dia. Ni-hard balls. In this series the test consisted of dropping a weight of 15 cwt from a height of 8 ft on to the ball supported by a V anvil. Here again the as-cast balls were the toughest (six drops) and the double-heat-treated balls were weakest (one to two drops). Balls showing intermediate lives (two to four drops) were those which had undergone a single heat-treatment at 275°C. It appears, therefore, that for service involving occasional very severe single-blow impact coupled with light repeated impact, the single heat-treatment, at that temperature, probably represents the best compromise.

FIELD TESTS

It is obviously most important to relate impact-fatigue life as measured on the drop-testing apparatus to service performance under commercial conditions. It was therefore decided to conduct a field test on 200 double-heat-treated (450°C+275°C) 2½-in dia. sand-cast Ni-hard balls. The test was made in the second compartment of a ball mill grinding dry nickel-oxide sinter. This mill, about 6 ft in dia., had a previous history indicating that it always broke a large proportion of as-cast white iron or Ni-hard balls. The results of the test on the experimentally-treated balls are given in Table III. No fracture occurred in any of the balls, and the wear factor of Ni-hard compared with forged medium-carbon-steel balls was found to be 15 to 1.

Further field tests are now in progress, on larger balls (4 in dia.) used in grinding raw stone for cement, in mills up to 8 ft in dia.

CONCLUSIONS

1. The impact-fatigue strength of Ni-hard is improved by the reduction of the austenite content of the

as-cast material, provided that the final structure is free of pearlite: the strength of a structure free of austenite and pearlite is improved by a light tempering treatment and the higher the proportion of tempered martensite, as distinct from bainite, the greater is the strength of the iron.

2. Heat-treatment at 275°C for at least 4 h, followed by air-cooling, considerably improved the life-to-fracture of a grinding ball, without lowering the hardness from its initial value of about 700 DPN.

3. Duplex heat-treatments of three types were found to be effective in increasing life-to-fracture:

(i) sub-zero treatment at −78°C or below, for 4 h, followed by tempering at 275°C for 4 h and air-cooling

(ii) 'intermediate-zone conditioning' at 450°C, for 4 h, followed by tempering at 275°C for 4 h and air-cooling

(iii) 'super-critical condition' at 750°C, for 4 h, followed by tempering at 275°C for 4 h and air-cooling.

Treatments (i) and (iii) both resulted in an increase in hardness of about 80 points DPN: treatment (*b*) produced a drop in hardness of about 30 DPN. Optimum life-to-fracture was obtained from treatment (ii).

4. Inclusions, flake graphite, porosity, pinholes, and deep surface oxidation all have an adverse effect on life-to-fracture.

5. Where conditions of occasional heavy single-blow impact are encountered, coupled with repeated light impact, a single heat-treatment at 275°C should be used, since this gives the best combination of toughness under both conditions.

ACKNOWLEDGMENT

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Symposium on practical aspects of pressing metal powders

Below are given synopses of 12 papers presented at a symposium on 'Practical aspects of pressing metal powders' held in London on 16 December 1960. The complete papers are published in *Powder Metallurgy*, no.6, with the exception of that by Martin, Knight, and Ellis, which will appear in no.7.

Some developments in metal powder presses by J. Oakley (The Manganese Bronze and Brass Co. Ltd, Ipswich). The requirements of presses for the production of parts from metal powder are listed. The historical development of modern presses from the early adaptations is described, their features being related to the demand for large and more complex shapes and the use of powders that are not easily formed. Reference is made to the difference in approach shown in the American multi-motion presses and the Continental combination of simple presses with complex tools used as a sub-press assembly.

Some fundamental studies in the cold compaction of plastically deforming solids by D. Train and J. A. Hersey (School of Pharmacy, University of London). Studies have been made of the behaviour under compression of materials which exhibit plastic deformation at normal temperatures, as exemplified by indium and lead. In particular, attention has been focused on the effects of die-wall friction and on the influence of the relative volume. The die-wall friction effects produced by a solid plug of the material were compared with those produced by a particulate fill of the same material when compressed under similar conditions, and a correlation of these effects with the shear strength of the material was made. A theoretical equation relating relative volume at either end of the compact is suggested.

Determination of hoop stresses induced in a cylindrical steel die by compacting metal powders by S. J. Bustamante and H. Sheinberg (Los Alamos Scientific Laboratory, University of California, Los Alamos, USA). Because of the lack of stress data, steel dies for compacting metal powders were designed in the past on the assumption of hydraulic pressure transmission by powders.

True die stresses existing in a hardened steel die during the compacting of various lubricated and non-lubricated powders have been measured by mounting strain-gauges on the periphery of the die at numerous points along its length.

Value of the hoop stress varied from approximately 0·05 to 0·40 of the calculated and measured hydraulic fluid stress. For a particular metal powder, the stress was a function of the average particle size, the powder height, and the amount of lubrication.

The displacement of gas from powders during compaction by W. M. Long and J. R. Alderton (Atomic Weapons Research Establishment, Aldermaston, Berks). A soap-bubble method was used to observe in detail the flow of gas out of powder masses during and immediately after compaction. The effects of powder material and size distribution, die size, pressing speed, and degree of compaction were investigated. The amount of gas trapped in the compact at completion of pressing varied from 12 to 83% of the initial amount of gas present in the spaces between the powder particles, over the range of compaction conditions studied. As expected, the amount trapped increased with increase in die size, with increase in pressing speed, and with decrease in particle size. Very little gas escaped during the latter stages of compaction, even at slow pressing speeds. The effect of a small punch/die clearance was examined in typical cases and shown to be minor, except with a coarse powder pressed at a high speed.

That trapped gas can produce cracks was demonstrated by making compacts containing varying amounts of trapped gas, other conditions remaining constant. With the particular powder used, once the amount of trapped gas had passed a certain level, the compacts tended to be fairly badly cracked. It appears, however, that cracks due to gas pressure alone tend to occur only when powders are rapidly compacted to very high densities.

Radial pressures in powder compaction by W. M. Long (Atomic Weapons Research Establishment, Aldermaston, Berks). A simple theory is advanced to explain the variation of radial (die-wall) pressure during compaction in conventional dies. The theory predicts that during the application and release of pressure by the punch, the radial pressure should follow a characteristic cycle whose form is determined by the elastic properties and by the yield stress in shear of the material which is being pressed. The theory is supported by experimental radial-pressure determinations on a range of materials.

The theory accounts for the residual radial pressures which dies continue to exert on compacts after removal of the punch pressure; according to the theory, these residual pressures arise through shearing of the pressed material, and have maximum values which are determined by the shear strength of the material. The mechanism of production of capping and laminar cracks by residual radial pressures is discussed in detail.

An apparatus for the measurement of radial pressures and powder/die friction coefficients at moderately high temperatures is described.

The influence of tooling methods on the density distribution in complex metal-powder parts by H. G. Taylor (Höganäs-Billesholms AB, Höganäs, Sweden). The theoretical movements required for the various moving tool elements during the pressing cycle are examined for several typical component sections. These theoretical movements are then compared with the actual movements of the moving tool elements in various types of tooling. The conclusion is reached that the conventional tool designs vary greatly from the ideal in many ways, permitting uncontrolled lateral powder movement during pressing and causing excessive density variation in the pressed compact.

Three major problems are apparent:

1. The use of a solid die for pressing compacts with varying section thicknesses results in an 'average' die movement which is always too great for the thicker section and too small for the thinner section.

2. The double function of the floating punch, which takes vertical pressure on its horizontal face while its vertical face acts as a die, presents a very difficult problem. The floating punch movement, controlled by its horizontal face, is always greater than the correct movement required to give minimum density variation in the portion of the compact formed by the vertical surface of the punch.

3. The various types of support used for floating punches rarely provide the correct timing, sufficient maximum load, or progressively increasing resistance essential to ensure equal density distribution within the powder during the pressing operation.

Suggestions for tooling, designed to solve some of these problems, are discussed.

The compacting of metal powders by explosives by W. T. Montgomery and H. Thomas (Research and Development Department, Imperial Chemical Industries Ltd, Nobel Division, Stevenston, Ayrshire). The paper describes a technique developed for compacting metal powders by the use of detonating explosives under controlled conditions. Aluminium, iron, copper, and steel powders were originally compacted by this means into solid cylinders. Graphite and other non-metal powders have recently been compacted, and modifications have been introduced whereby annular cylinders may be formed. This novel technique may find application in cases where existing mechanical methods of powder compacting are not adequate.

Aspects of the volume production of green porous bearing compacts by M. A. Pound, A. E. S. Rowley, and J. E. Elliott (Bound Brook Bearings Ltd, Lichfield, Staffs). The history and methods of manufacture of self-lubricating porous metal bearings are briefly outlined. The importance of achieving appropriate quality at each stage of manufacture, and particularly during compacting, is emphasized, and the qualities desired in a green bearing compact are detailed. Various factors relating to the economic large-scale manufacture of green bearing compacts are then considered. The virtues of elemental powders and the influence of lubrication upon powder mix properties and pressing and ejection of compacts are discussed. The special powder-flow problems associated with long, thin-walled bearings and the advantage, in this respect, of a moving core rod are described. The particular difficulties encountered in compacting such bearings are stated, and special consideration is given to the ejection problems involved. It is concluded that limitations of bearing length and wall section must be accepted.

The processing of enriched uranium oxide/paraffin wax mixtures by L. D. Huckstepp and G. V. Day (Atomic Weapons Research Establishment, Aldermaston, Berks). A process for the production of 1-in cubes in an inert gas atmosphere, from enriched uranium oxide and paraffin wax powder mixtures, is described. A general description of the type of equipment used is given and the procedure and safety precautions required for handling this type of radioactive material are outlined.

Hot pressing of ceramic powders by A. G. Thomas and H. J. Jones. (The Plessey Co. Ltd, Caswell Laboratories, Towcester, Northants). The processes involved in the production of dense ceramics from powder materials by the simultaneous effect of pressure and heat at temperatures above 1 500°C are outlined. The factors leading to the choice of this method of fabrication, and the general principles involved in hot pressing, are first dealt with, and the advantages and disadvantages of the process are then discussed. Current techniques are described and their limitations considered. Examples of typical applications are given, and possible lines of future development are indicated.

The isostatic pressing, vacuum sintering, and swaging of thorium powder by H. Lloyd and A. E. Symonds (Atomic Energy Research Establishment, Harwell, Berks). The isostatic pressing of calcium-reduced thorium powder into round bars and tubes, before vacuum sintering and swaging, is described. The simple equipment allows powder filling to be carried out in an enclosed system, thus avoiding fire and health hazards at this stage. A number of bars or tubes, of varying length and diameter, can be pressed simultaneously. The technique has certain advantages over conventional die compacting.

The effect of pressure on density and hardness through the bar section before and after sintering at various temperatures has been studied, and the optimum conditions determined for the manufacture of dense bars with high metal efficiencies (98%). Details are given of the microstructure and mechanical properties of thorium bars in the sintered, swaged, and annealed conditions.

The forming of hollow shapes in beryllium by loose sintering and hot pressing by A. J. Martin, R. A. Knight, and G. C. Ellis (Atomic Weapons Research Establishment, Aldermaston, Berks). Two methods for forming shaped bodies in beryllium by powder metallurgy are described and compared. The requirements for uniform densification during hot pressing are discussed, and it is concluded that a double-pressing method is essential if thin-walled hemispherical shapes are required.

Powder Metallurgy, which appears twice a year, is the official organ of the Powder Metallurgy Joint Group. It is obtainable by annual subscription at 25*s* (post free) to non-members; members of The Iron and Steel Institute and The Institute of Metals may obtain it for an annual fee of 10*s* (post free).

STAL *in English*

Number 9 (September 1960) of the cover-to-cover translation of the Russian journal *Stal'* has been published and no. 10 (October 1960) should appear early in January. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

Report of the Thirty-ninth Engineers Group Meeting

The Thirty-ninth Meeting of the Iron and Steel Engineers Group of The Iron and Steel Institute was held on Wednesday and Thursday, 6 and 7 April 1960 at the offices of the Institute, 4 Grosvenor Gardens, London SW1. The Chairman of the Group, Mr F. B. George, was in the chair. Four papers were presented and discussed during the sessions of the Meeting. The papers have already been published in the Journal. *The discussions are given below.*

Discussion on plate-mill design and layout

At the first session a paper entitled **'Some aspects of plate-mill design and layout'**, by *A. Marshall* (Consett Iron Co. Ltd), which was published in the February 1960 issue of the *Journal* (**194**, 240–248), was presented by the author.

Mr **Marshall**, before presenting his paper, made the following correction: 'In Table I, under the column Algoma, the plate-mill speed should be 144 in/min and the slabbing mill screw-down should be 190 in/min.'

Mr **D. D. Ramsay** (Colvilles Ltd): The ideal plate mill would be one which would roll a plate uniform in cross-section, dead flat, clear of all surface blemishes, and able to pass any test given it by the inspectors.

Before we could get a mill of that kind, we would have to consider a thing that has not been mentioned today, namely, the question of yield. Being an operator, I would say automatically that I would want an 86% yield from slab to plate and 75% at the very minimum from ingot to plate. To get that it is almost imperative that all slabs should go cold and be flame dressed, thus taking away any chance, or reducing the chance, of surface blemish. To do this requires a heating furnace that will heat the slabs uniformly at top, bottom, and centre, and also produce scale that can be easily removed, preferably before the main rolls, to avoid the problem of getting rid of rolled-in scale, particularly on the thick plates.

Automatically our thoughts must turn to output, and I would agree wholeheartedly with the Consett figures of about 10000 tons of finished plates. I would ask for $\frac{3}{8}$ in to $1\frac{1}{4}$ in, hoping that the engineers could squeeze in 5% of $\frac{1}{4}$-in plate capacity.

So far as the mill itself is concerned, naturally it must be of a robust design. It must also be sufficiently fast to get a yield of 10000 tons/week, and that being so, the centring gear, adjusters, and the speeds of adjustment of the rolls must be of fairly high capacity. I should like, if possible, an automatic gauging of width from a remote control, automatic gauging of plate, high-pressure water sprays to keep the plates clean, and rotary shearing to guarantee accurate shearing; also automatic marking, a process that is not confidently employed in the UK, and automatic branding, stamping, and stencilling of plates.

Mr **T. Coxon** (Consett Iron Co. Ltd): When we considered these extensions at Consett, there was, of course, a considerable increase in demand in power. We have our own power station with a capacity of 45 mW, and we had to decide whether or not to extend the station or bring in the supply from the North Eastern Electricity Board. The overall economics indicated that it would be cheaper in capital and in running costs to bring in a supply from the board. Had we extended our own station for a mill of this kind we would have gone in for the orthodox Ilgner drive, but the bringing in of a supply opened up the possibility of a rectifier drive.

In the UK at the time the decision was taken there were no rectifier fed reversing mills in operation; the earliest unit to go into production was a 750-hp mill scheduled to roll at the end of 1958. The Consett mill with a cut-out of something like 30000 hp was a totally different problem, and hitherto the generating boards have fought shy of such loads because of the voltage dip associated with heavy peak loads. In the case of the reversing mill drive supply from the Ilgner set, these are absorbed by the flywheel. With rectifiers the power peaks are transmitted directly on to the line; further, when the piece enters the mill it is necessary to take the power at low voltage: this means a very low power factor on the rectifier which increases the voltage dip for the given load. It is also a problem of harmonics. When connecting a large capacity of rectifier equipment care must be taken to ensure that the harmonics introduced into the ac system are not excessive. In the early days of the application of rectifiers trouble was experienced and equipment had to be modified. When this problem was put to the North Eastern Electricity Board they were most helpful, and since 1958 we have had many discussions with them and also with the Central Electricity Generating Board. Eventually it was decided that this particular application from rectifiers was acceptable, and so we are putting in the first large twin-drive reversing mill for rectifiers in the UK.

Mr **J. Dodd** (Appleby-Frodingham Steel Company): The first question I should like to ask is whether 500000 tons is to be got in the first phase, with the single-stand mill, or whether it is in a year or two's time when the roughing mill is added. If it is now, what sort of slab weights are contemplated? I think that if the proportion is of any size at all, then 10000 tons/week is optimistic if it is expected in the first phase.

Mr Marshall mentioned the slab-scarfing train. Does this mean hot scarfing in the mill train? With regard to the descaling box, he mentioned that there are three header pipes to cater for variation in thickness. Has thought been given to having one header pipe of variable height to cater for different thicknesses, and if so, has the idea been rejected?

Mr Marshall did not mention the position from which the mill is to be controlled. I suppose that this matter will arise on the later papers on control generally, but where is the control in relation to the mill, and how many men are intended to drive it?

In his reference to shear bow, I think Mr Marshall said that the rocking-type shear is not much better than the inclined blade but my experience is that shear-bow is a good deal less from the rocking blade.

Press-quenching is a term with which I am not familiar, and I should like to know more about it.

Mr **Marshall:** In reply to the question about what our anticipated outputs from this mill will be, we realize as well as Mr Dodd that 10000 tons/week on a single-stand mill is a large amount of plate. If it were possible to predict to our management the order book position when work on this mill is started, we could say whether we are going to roll 10000 tons/week. It is possible to roll this quantity on a single-stand mill provided that the order book is right.

With regard to the average slab weight, we are anticipating an average of about 3 tons.

On slab-scarfing, we are primarily thinking of the 20-ton semi-portal slab-scarfing crane for the purpose of turning over single slabs and also for the saving of overhead crane usage. This mill will be rolling in August 1960, but there are still one or two small problems that we have to solve, and we are not quite convinced that there is a first-class scarfing machine available. We have discussed and looked at one or two different types of machines, and will be looking at another in about three weeks' time. So the answer is that at the moment it will be hand-scarfing, but possibly we will buy an automatic scarfing machine.

With regard to the scaling box, we did consider one header, but this would have meant putting telescopic glands on the outside of the box, and this we did not like. Therefore, we decided that we would go ahead with three separate header pipes for the three slab thickness ranges. If we find that we do not get good results from this, we can always come back to a single header.

I omitted a description of the position of the mill control pulpit. The desks will be arranged so that the operators will be looking at the mill as shown in Fig.*A*. Whether we operate the mill with one or two men is a question that is open to a great deal of debate. My own opinion is that there is too much work for one man in this pulpit, but no firm decision has been taken yet. I think that we will start with two men, but the control desk will be so arranged that it will be possible to go on to one-man control.

I am still not convinced that the claims of the manufacturers for the rocking-type shear are 100% trustworthy, but I do go part of the way with them. I think I said that the shear-bow is less – how much though, I would not like to guarantee; but even on the installations that we have seen with these rocking shears, we still find that occasionally men must be employed to guide the scrap into the shears.

With regard to press-quenching, this is for the treatment of special steels, and involves a machine which has a great number of platens top and bottom which come down on the under-side and the top of the plate to hold it in position while the temperature is rapidly reduced from 900° to about 250°C.

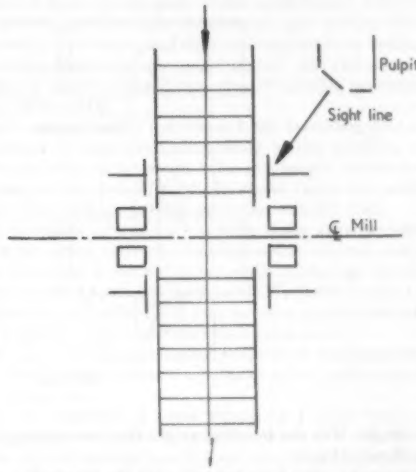
The **Chairman:** The reason we decided to go ahead with press-quenching was that we felt, in putting in this mill, that we should try to anticipate customers' requirements as well as look after those that we knew existed. Our feeling is that the demand for special types of steel will have a tendency to increase, as will the demand for heat-treated large plates. Of course, this press-quenching equipment is rather similar to the plants which were used during the war for heat-treatment of tank armour plating.

Dr **W. S. Walker** (Round Oak Steel Works Ltd): With regard to fuel economy, this plant lies three-quarters of a mile from the melting shops. Is it the intention to transport the ingots in some form of insulated containers? Also is it intended to shift the ingots by road?

The finishing bay area is given as 10 ft²/ton week output. This strikes me as being a little small, particularly if it is compared with some of the other mills. Is it intended to warehouse the plates in this area awaiting shipping instructions etc?

Finally, has consideration been given to the installation of data recording in the plant so that there is complete, automatic work study being thrown up every day?

Mr **Marshall:** With regard to the transporting of ingots, in the first phase there will be no ingots used on the plate mill. What



A *Position of mill control pulpit showing operators' sight line*

I had in mind in connexion with the road transport was that we did consider transporting all our slabs from the present slabbing mill by road to this plate mill. Again, there are differences of opinion on this, but we feel that our economics are such that it would be cheaper to transport by rail so far as the first stage is concerned. So far as the second stage is concerned, that has not quite been established, but I think that if we do go ahead with ingot rolling on the plate mill, some form of closed containers must be used.

With regard to the finishing bay area, I do not know of any operator who says that he has got enough room. We thought we had been very liberal on this finishing bay area, and we think that by the installation of the portal cranes we will save a great deal of floor area, although this remains to be proved.

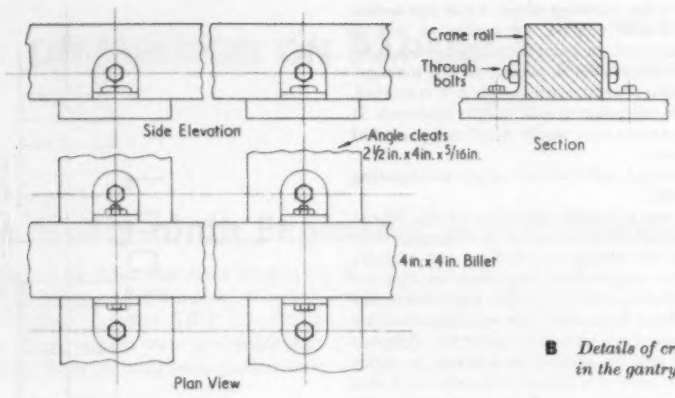
On the question of fuel economy, we obviously cannot treat this plant on its own. It has to be considered in conjunction with the steam and fuel balance for the rest of the works. Because the site was isolated, it meant that even if we had had the gas available to feed to these furnaces, we would have been faced with quite a high capital expenditure for gas mains etc.

We also looked into the question of straight comparison of capital costs between oil-firing and mixed gas-firing, and found it was cheaper for us to put in oil-firing equipment. Against all that, we found on the fuel balances that we took out for the rest of the works, that we would not have had sufficient gas available to run these furnaces. Therefore, we went ahead exclusively with the use of fuel oil.

The **Chairman:** These questions of gas balances are, unfortunately, changing almost every hour now. With the old conventional ideas before we started oxygen steelmaking, one could more or less make up one's mind what the balance was, but the way things are going now it is almost impossible to determine from day to day and almost from hour to hour what the figure is going to be. Therefore, as this was an independent site, we said that we would fuel it independently.

With regard to the loading bay, it may not have been noticeable in the layout that there is quite a substantial area in which the loading bay may be extended, but I do not want Mr Fraser or Mr Henderson to feel hurt when I say that my experience of plate mill loading bay stocktakers is that if you give them 100 square miles, they will cover it with plates! I always feel that the right place for plates is in the wagons.

Mr **R. Jamieson** (Colvilles Ltd): With reference to roll changing, Mr Marshall has adopted a sledge change for work rolls and a narrow window design, due, he says, to available housing casting weight, although in the paper he states a preference for



B *Details of crane rail fixing in the gantry*

nested chocks. Was the housing weight the determining factor or were there others?

With regard to the heat balance, did Mr Marshall consider the question of hot cooling on the skid furnaces in view of the amount of heat which can be regained?

Mr **Marshall:** With regard to housing weight, I did say in the paper that I preferred the nested chock design. The reason is because it would be possible to introduce small rams between the two chocks, which one cannot do with the parallel width chocks. The reason we could not go to the nested chock design was because we were restricted in the housing weight. There are a number of people who have different ideas on roll changing; but we have changed rolls on our slabbing mill for a long time now with the bogie arrangement, and we have had very good service from it. My own opinion is that one can change rolls as fast with a bogie as with a porter-bar.

On the question of steam raising, we did consider this. There is no doubt in my mind that steam raising on the slab furnace skids can be very economical. Had we had a very large steam requirement on the site, then I think we would have given it a little more serious consideration, but I am always of the opinion that it pays to keep the back door open, and there is no reason at all why such a furnace cannot be converted. I am sure that in the early stages the operators will not like this question of steam raising, because in fact it then becomes a boiler and is subject to annual inspection, but I do not think that is insurmountable, because there are many plants which are operating on this principle on the Continent.

Mr **Fraser** (Consett Iron Co. Ltd): I should like to refer again to one feature of our mill that involves roll check design. We will roll floor plate on a mill located some 150 to 200 ft from the main stand and are a little worried about temperature as we are not sure about the maximum length floor plate we can roll to ensure a good pattern. Thus we may be forced to use a very small slab for floor plate rolling, and we had to provide for closer centres between the mill and feed rollers than is usual on most plate mills. This meant that we had to abandon the nested chock design which otherwise we would have considered to be most desirable.

The **Chairman:** This question of steam raising on the slabbing furnaces comes back again to the heat balance in an integrated works. It is pleasant, of course, in the OH shop, for instance, to say that one has an attractive steam credit from the waste heat boilers, but it is not much of a credit if one has no use for the steam. That, of course, is one of the difficulties. Anyone who is contemplating one of the new oxygen steelmaking processes, particularly the straight LD, will find that he has a difficult problem there. One is bound to cool the gases in order to have an efficient gas-cleaning, fume-cleaning plant, and in the process one raises such an enormous amount of steam that for a period one might be able to close down the whole power station. It is one of those problems which is not only difficult in itself, but is very difficult to control. There are very big peaks on the waste heat boilers of an LD plant, which make it necessary to fire the boiler in order to keep a reasonably uniform load on it. In an integrated works requiring the sort of output of steel that a large LD plant will give, one really has a position where one does not need any other steam raiser in the works.

Mr **J. M. Borland** (Colvilles Ltd): Could Mr Marshall say what angle of blade in a conventional shear would give the equivalent of a rocking shear? Also, what is the estimated frequency of roll changing? Finally, how are the crane rails fixed to the gantry?

Mr **Marshall:** The first question is one that I would not like to answer; it is one for the designers. As to the frequency of roll change, it will be twice, or possibly three times a week.

Mr **Fraser:** It will be more often than that.

Mr **Marshall:** Finally, we have fixed the crane rails in the gantry as shown in Fig. *B*.

Mr **J. C. Gordon** (Colvilles Ltd): What length of plate can be made effectively out of a mill of the type described? Mr Marshall has taken 90 ft as the maximum. Is this his view as to the maximum length of plate that can be taken from a plate mill of this kind?

There have been built into the plate mill two very elaborate shearing lines, both capable of 8000 tons/week. Is it possible to schedule the mill in such a way as to keep these two lines reasonably occupied?

Mr **Marshall:** Mr Fraser will probably answer the question, but there is one point I should like to make. It is that in laying out this mill and in designing these two shearing lines, we have our sights on targets ahead of 10000 tons. Otherwise we would not have considered putting behind this 132-in mill a 160-in stand.

Mr **Fraser:** In answer to the first question regarding maximum plate lengths, this was determined not only by the mill but also by the need to transfer the rolled plate across the building. Our columns are on 100-ft centres so we have settled on 90 ft as a reasonable maximum rolling length. Possibly the mill could roll to 120 ft or more on some sizes.

Regarding the shearing lines; our rotary line will handle anything up to $\frac{3}{4}$ in in thickness and our heavy line anything up to $1\frac{1}{2}$ in. In fact, about 80% of our current order book is made up to plates $\frac{3}{4}$ in or less in thickness, thus there is little doubt that the actual split to the two lines will be determined by minute-by-minute conditions to attain maximum throughput.

Another aspect of reported impressive throughputs of fully mechanized shearing lines is that we are perhaps inclined to overlook cross-cutting requirements. I can think of one American mill which has a very impressive throughput for a

single shearing line but in fact something like 40% of their mill output is directed to a single repetitive order in 40-ft lengths.

In our case, about 56% by number of all the plates that we sell are 8 ft or less in length. The throughput of a shearing line is governed by the number of cross-cuts involved.

On the question of manning we propose in the beginning to man only the heavy line until it has become an obvious bottleneck, then the light line will be brought into use.

Mr **Dodd:** I would say that the handling and loading of scrap is a bigger problem than the handling and loading of plate. The quantity is smaller, but it takes more looking after, moving about, and disposing of than the plate itself. I think it is time that the designers catered for scrap disposal by some means that do not ultimately depend on an overhead crane for moving it. We have a fairly modern system of cutting it into small pieces and conveying it by various means into scrap boxes which do not appear to have the capacity for which they were designed, but which ultimately have to be picked up by overhead cranes and tipped into something. I would like to see the scrap chopped up into small pieces and taken off by some means outside the mill building so that we do not have to depend on plate loading cranes to load scrap.

Mr **T. Harris** (Colvilles Ltd): I should like to ask about some of the features that are being incorporated in the Consett Plate Mill. First, with regard to the descaling box, Mr Marshall states that there is one functioning on the Continent. Does he know whether it is handling alloy steel slabs? If so, is it efficient in removing the scale from the alloy slabs which are more difficult to descale than plain carbon steel slabs? Have any special provisions been made for dealing with the alloy steel slabs, as obviously there will be such slabs in view of the quench press? Further, has a flame-cutting set-up been incorporated in the flow line to deal with the thicker plates?

Finally, Mr George claimed that he was very niggardly with money, but he appears to have been more than generous as regards slab heating facilities. Are there two continuous furnaces of 100 tons/h capacity in addition to the two electric soaking pits?

Mr **Marshall:** On the question of the plant on the Continent rolling alloy slabs, the answer is 'no'. So far as the treatment on our mill is concerned, we will be putting in cooling pits for this material. In connexion with the thicker plates, there is quite a big area laid out for automatic machine cutting of the plates immediately to the left of the cooling beds.

With regard to slab heating, we are starting with two 100-ton continuous furnaces, with electric soaking pits additional. The soaking pits were primarily put in to handle the thicker slabs which we contend cannot be handled efficiently through continuous furnaces, and which will be, in our case, from 10 in upwards. Those pits will give us about 2800 to 3000 tons/week additional heating capacity.

A **Member:** I should like to ask Mr Marshall what he considers to be the ideal balance of slab stocks. Also, is it intended to identify each slab against specific plate orders? Does he see any virtue in the weighing of slabs after dressing? Is it intended to mark the plate by using a marking machine? After marking with this machine, where is it intended to brand, stamp, and paint the plates? To ease the loading bank problem of handling plates, is it intended to schedule the mill by customers' orders?

Mr **Fraser:** Concerning slab storage for our planned output, 7000–8000 tons of slab stock is adequate. The bulk of our slab storage will be out of doors with handling done by a 40000-lb capacity fork-lift truck.

Concerning slab identification, we do not propose to change our present system wherein each slab as it traverses the slabbing-mill transfer bank is hot stamped by a pneumatic stamper.

Concerning scheduling by customer and the building up of ordered plates into rolling plates, we do not propose basically to change our existing system wherein we segregate orders, as forwarded to us by our plate order department, into qualities, then within qualities into thicknesses, and within thicknesses into widths, and so on; and then strive to build up rolling plates to the maximum dimensions that the mill can handle. This frequently involves the combining of several customers on a single rolling plate.

Slabs are ordered to suit these built-up rolling plates but in fact about 20% of the slabs arising at the slabbing mill (so-called back-end slabs) are of unknown length before the actual shearing of the rolled ingot. In these cases the build-up of plates must be done to conform to an existing slab.

We schedule orders on a weekly basis and, provided that scheduled orders are rolled and delivered on time, there seems to be no point in securing complete customer orders in sequence at the expense of mill yield. We firmly believe that to operate the mill efficiently and achieve acceptable yields we *must* combine orders into maximum size slabs.

I do not see any particular purpose in weighing slabs. We know from periodic check-weighings what our deseaming and other losses are.

On the question of plate stamping I wish that someone would invent a satisfactory machine to do that job. To date no one to my knowledge has devised anything better than a box of hand stamps.

We are at the moment working on a scheme of our own in this connexion but it has not yet been given a trial.

Mr **R. G. Atkinson** (Dollery and Palmer Ltd): There are one or two points I should like to raise. The first is on the question of slab storage being out of doors. Is that deliberate or accidental? Would there be any saving in the later conditioning of the slabs by having them under cover, or are the economics of providing this cover such that it is not worth while?

With regard to the scarfing of slabs, Mr Marshall mentioned that there is a 20-ton crane provided for slab turning, and I am wondering if the problem of turning over slabs presented any difficulties, and what method was finally decided upon.

On the mill itself, there are individually driven rollers, and I should be interested to learn whether the method of rolling is such that it is necessary to turn the slab both on the ingoing and on the outgoing side, and if so, whether conical rollers running in opposite directions are provided for this purpose. A Continental plate mill uses this method on the outgoing side but was provided in front of the mill stand with three disappearing dogs. In view of the Continental practice of providing rotary slitting shears with blades of the same diameter, what considerations led Mr Marshall to decide upon using a machine having a larger bottom blade and a smaller top blade?

Mr **Marshall:** This question of slab storage was partly decided on the grounds of economy.

On the question of scarfing of slabs, we did consider putting in a crane which would pick the slabs up and turn them over mechanically, but the cost was so great that we rejected the idea straightaway. We then arrived at the conclusion that the cheapest way was to put in an ordinary conventional semi-portal crane with a fixed mast which could pick up the slabs on edge with the magnet and just turn them over. We think that is simple and efficient.

With regard to turning on the mill, we have turning on both sides, by means of conical rollers.

With regard to rotary shears, I think the answer is that in America they say that it is right to have the small and the large blade. All this comes back to the question of edge condition. The Americans claim that one gets a better edge with the small and large blades. The Continental people say that one gets a better edge with equal blades. I do not know which is right, but I think there is very little difference.

WRITTEN CONTRIBUTION

Mr **H. R. Mills** (BISRA) wrote: I was interested to learn from Mr Marshall's paper that the speed of shearing of plates was likely to be governed by the speed at which they could be marked out. I wonder, however, whether the introduction of

automatic marking by machine is the right way of overcoming this problem.

At present the shearing of plates to size is carried out in two separate stages. The first stage is for the marker to read written instructions on the card or other document pertaining to the plate and to mark cutting lines or guide lines for the shear operator to follow. He does all the interpreting of instructions and actual measuring out. The shear operator merely has to use the guide lines on the plate to guide his actual cutting operation.

When we get to the stage, however, where marking out by hand is too slow and we have to have a marking machine which draws the lines automatically, we have to solve one of two position control problems. Either the marking head of the machine must be set to draw a line in a required position, or the plate itself must be moved to a required position underneath the stationary marking head. The job of the marker is to make the machine or the plate take up the required positions in accordance with his written instructions.

Once we have learned how to control a marking machine in this manner it is scarcely more difficult to control the shear in a similar manner. In practice, of course, it is probably the position of the plate under a stationary shear that would be controlled. I am suggesting, therefore, that rather than try to solve the problem of position control of a marking machine, we should go the whole way and attempt to control the position of a plate under a shear using similar techniques. It would be just as easy for the shear operator to work from his written instructions as it is for the marker to do so. The marking machine then becomes quite unnecessary and the only marking out which would have to be done would be hand marking out of sketch plates.

Discussion on the modern plate mill

At the second session the paper **'The modern plate mill'** by *M. F. Dowding, C. Sturdy,* and *A. A. Thomas* (all of Davy and United Engineering Co. Ltd), which was published in the April 1960 issue of the *Journal* (**194,** 486–494), was presented by the authors.

Mr **M. F. Dowding:** It is the policy of our company to propose rolling mills based on production requirements; we like steelmakers to say what they want to make and we then try to propose a mill and equipment to produce the end-product desired. Three or four years ago Mr Cartwright and I wrote a paper for the South American Symposium on Rolling, and Mr Cartwright said: 'You must realize that flat rolling means reducing a thick piece of steel into a very thin piece. It is a metallurgical problem; let us get the metallurgical answer right and then see what equipment is needed.

Mr **A. A. Thomas** outlined the contents of the paper and invited Mr Sturdy to comment on the question of work roll and back-up diameters now being installed'.

Mr **C. Sturdy:** Table I gives particulars of a few fairly recent mills which are in operation or on the drawing-board. For the early roughing passes on a slab a large work roll is needed to ensure a reasonable angle of bite whilst the drafting is heavy, whereas during the finishing passes a smaller work roll is advantageous particularly for finishing thin plates. Single stand plate works which have to rough and finish on the same pair of rolls generally employ the larger work rolls. With regard to back-up sizes, the first two mills listed are rather old; the present trend is to increase the back-up size to give better shape and stiffness.

On the subject of roll balance, the essential feature is that all the bearing clearances and mill clearances should be taken up. The various possible configurations are shown in Fig.2. On plate mills there is the problem of getting the breast rolls close up to the mill, and this requirement influenced greatly the design of the roll assemblies. It is important with reversing plate mills that the balance pressure should be applied equally to the top and bottom roll sets, to ensure that slippage between work and back-up rolls does not occur on reversal.

Some screwdown speeds are given in Table III; some plate mills had higher speeds on the roughing mill. These higher speeds require larger motors with consequent increase in inertia, and on normal pass changes the response time of the higher speed screwdown showed no gain over a lower speed system.

Mill tables should be of the alternate conical type. They are close pitch, about 22½ in, so that with the conventional line-shaft drive it was necessary to put a drive on each side of the table, driving alternate rollers. Tables are being built for Consett with an individual motor on each roller. This eliminates all gearing and results in an extremely simple table construction, fabricated from thick slab. There is hardly any difference in cost between the two designs and therefore individual motor drive has been preferred on account of reduced maintenance.

The essential requirements for breast rollers are close pitch and close proximity of the first roller to the mill. In some older designs chain drives are used or a multiple-spur idler system. Neither of these is ideal for handling heavy slabs, and individual drive for each roller through gear couplings is preferable. The roller is mounted in self-aligning bearings and there are seals to keep out scale and water. Any that gets round the back is channelled in a special way and washed away, so that this is a relatively scale-free job.

To change a roll the whole roll assembly can be easily lifted out. The solid-mounted type has also been very successful. We will have to wait and see which of the two types, solid-mounted or spring-mounted, is better in the long run.

Mr **Thomas:** Have you any comments on yields which can be expected from plate mills which are operating today?

Mr **Dowding:** We heard this morning from Mr Ramsay that this is a fairly controversial subject. It is on a continuous strip mill that the highest yield can be obtained, but there is a very strict limitation on the width; no mill in Europe is wider than 80 in, so the widest plate is 74 in. Also, it is necessary to have an order book which lends itself to continuous strip mill operation, and perhaps it is easier to achieve this at the narrower widths.

The yields which we give were obtained by a team going round the world. On this journey, which took place about two years ago, we learned far more in Europe than in the USA. We knew that many new mills were projected in this country, and felt that we ought to know something about plate mills and their operation. We visited a number of plants in Holland, Germany, and the USA, and the figures which we obtained are given in Table IV of our paper. When the new plants, which are not yet in operation, but have all the features recommended from these investigations, and also some recommended by other workers, are in operation we may well get the yields asked for by Mr Ramsay during the first session.

Mr **Sturdy:** The typical plate mill layout shown in Fig.7 is a good example. There are thousands of possibilities, depending on what you want to roll, the nature of the site, how much money is available, and many other factors.

Figure 7 does not show the provision made to side-track a

plate to practise controlled finishing temperature rolling. The maximum length which can be dealt with is 120 ft, and, to make it reasonably easy to handle at the finishing end, the plate can be divided by a hot plate shear. Before the cooling banks a hot leveller is required. There are as many cooling banks as required for the output, preferably of the cast-iron grid type, which gives better cooling and a flatter plate. There are turnover arms for inspection purposes. From this point the flow is split; light plates, up to ⅜ in, go down the light shearing line and the others down the heavy shearing line, and are then piled. If 20% of the plate is reduced to scrap it is necessary to have efficient scrap-handling, and the plate shears therefore have automatic scrap chopping equipment, and the scrap is placed automatically in buckets or even melting shop changing boxes. In the layout shown it would be possible to arrange for three bays, the centre bay being purely for scrap handling.

Mr **Thomas:** In addition, there are a few further points on which we should like to comment. We have said in the paper that there are three ways of scale-breaking; the descaling box with high-pressure water jets, the heavy edger, and the two-high mill. At first sight the descaling box might be thought inadequate for descaling duty, but at Oberhausen it is used on the 132-in plate mill and two of the mills that we are currently building have this descaling provision. On the other hand, the two-high mill as a scale-breaker has the advantage that it can also do work and even assist in broadsiding. Although a strip mill is using edgers for scale-breaking, on plate mills the limited duty which they can perform probably does not justify the capital cost involved. We recommend, therefore, that provision be made at least for a two-high mill. Failing this, a descaling box will be sufficient.

On the mill itself a major question is the selection of roll-neck bearings. The selection should be roller bearings for the work rolls and Morgoil bearings for the back-up rolls. The former were more expensive in initial cost even when lubrication systems were taken into account, and their running cost was greater, since the complete bearing had to be replaced when wear occurred, and during its life, accuracy became progressively worse and load-carrying capacity at high speed fell off markedly compared with the Morgoil bearings. The latter can be designed to have a larger capacity at all speeds than the roller bearing with a given space limitation.

We have discussed plant to deal with plates of 2 in or less. There is, however, an increasing demand for thicker plates than this, and the problems of handling these have not been fully dealt with. So far as hot levelling is concerned, any leveller to deal with a plate of more than 4 in thick is bound to be as expensive as a mill stand, and even up to this thickness a hot leveller must be a compromise if it has also to deal with the lighter products. Any plate over 2 in thick must be cut in a separate bay with oxygen cutting torches, because the cutting is a slow process and the plates cannot be cut in the production line. At Luken's the flame-cutting rate is speeded up by using higher gas pressure. British Oxygen are carrying out research on this.

Mr **N. Hanlon** (Dorman Long (Steel) Ltd): Referring to the mill stand proper, I am sure most of us appreciate the careful thought suppliers put into their mills, and he would be a bold man who would be prepared to state that one design was so much better than another. To my mind it is a matter of cost. In this connexion, would the authors give us some indication of the cost of complete plants for rolling steel plates, say on the basis of cost per annual ton? Would they also enlarge on their statement that there is no difference in first cost between shaft-driven roller racks and individually motorized rollers? How do the power consumptions compare?

They recommend two shear lines, one for light and the other for heavy plates. I agree with their recommendation for rotary shear lines even though their use can affect yield to a certain extent, but I should be interested to hear their comments on the merits of the 'large and small' blade design as compared to the 'equal blade' design. Referring to the heavy shear line proposals, are the authors adamant in their recommendations or are they merely following fashion? In many mills the light plate demand is around 55–60% and more, and the demand for plates thicker than 1½ in is increasing. As the upper shearing limit has been set at about 1½ in for the rocking blade shears, above that limit flame burning being advocated, would it be a proposition to insert fast burning equipment in place of the shears in the heavy shearing line? The provision of cheaper oxygen at steelworks may also have an influence on this decision.

Beyond the shears, of course, the real difficulties start for the management personnel in the sorting of orders. Most mill designers seem to be so busy dealing with the intricacies of breast roll drives etc., that they are exhausted by the time they reach the final shears. It was, of course, the same with section mills for many years. At Dorman Long we have at least tackled the problem on our medium section mill and beam mill, and we have had a fair measure of success in sorting orders on the run. I know of only two Continental plate mills where the problem has been tackled, and of these only one seems to have the courage, or the money, to insert a fairly good arrangement. I should be interested to hear the authors' views on these matters.

We have heard that we should install four-high mills to give a good flat plate, and then the best of cooling bed equipment to keep the plates flat, and then to round off the installation we are recommended to put these lovely flat plates through a first-class cold plate leveller. Why is this so?

Mr **Thomas:** So far as the cost of the complete plate-rolling plant is concerned, including buildings, electrics, furnaces, and services, it is difficult to be exact, because so much depends on the degree of mechanization adopted, whether or not there is a separate slabbing mill, and so on; but for all the plate-rolling part of the plant between £20 and £30 per annual ton is about the figure. So far as the rolling tables are concerned, individually driven *v.* line-shaft driven, the main tables on a heavy plate mill together with their electrics are worth about £250 000. Of that we can say that about 75% is for mechanical equipment and 25% for electrical equipment in the case of line-shaft-driven equipment. For a design with individual drive the cost still comes to about £250 000, in fact, on one of the plants which we are building at the present time I think that the individual drive comes out a little cheaper, and of that sum 40–50% is for the mechanical equipment and the remaining 50–60% for the electrical equipment. So far as power consumption is concerned, we would expect it to be about the same in each case.

Mr **Sturdy:** For rotary shears we prefer the smaller top blade. We find with this type of shear that the top blade takes about 70% of the cut, the large bottom blade acting as an anvil. With the smaller blade there is a lower blade load, which we believe gives a better finished edge.

On the question of burning plates in the line, I think that for side cutting, burning would be quite good. With the ordinary shear it is necessary to take a number of bites when side cutting, so that burning will have some advantage if it can be fairly fast. I do not think that cross-cutting can be done by burning as fast as it can be done by shearing.

With regard to sorting on the run, we can develop these ideas only if operators will tell us what they want. If you tell us what you want to sort and how you want to sort it we shall devise a scheme to do it, but up to now that problem has not been put to us.

Mr **Dowding:** The question of the rocking blade shear has caused a good deal of discussion over the period during which these mills were being developed. Let us be quite fair. The decision was not made on our recommendation; the decision was made on the recommendation of the team of engineers and operators from the steelworks buying the mill, who went round the Continent and then met us. We told them that the rocking blade shear would cost more than the guillotine,

but they decided to buy the more expensive shear. The only people who have them in operation did not buy them from us, but the machines at Appleby-Frodingham are very similar. Perhaps we can have someone at Appleby-Frodingham give some indication of whether or not they are satisfied with the operation of their rocking shears, which I have seen in operation and which impressed me very much. Such an indication would be extremely valuable for people who are on the edge of the same decision. The rocking blade shears that I saw at Appleby-Frodingham produced a very flat plate. Before that they used an ordinary guillotine shear, and they may be able to tell us whether or not they have had as much improvement as the price appears to indicate that they should have.

The **Chairman:** It seems to me that there is one point which tends to be overlooked on the question of the two shear lines, the heavy and the light. It is obvious that there are more light plates per ton than heavy plates. A light shearing line can shear light plates but not heavy plates, while the heavy shearing line can shear both thin and thick, within reason. If, therefore, we put in only a light shearing line we cannot tackle the heavy plates, but if we are rolling a higher proportion of light than of heavy plates we can shear them on both the light line and the heavy line. That seems to be a point which has not been fully appreciated. We must have a heavy line unless we are going to gas-cut everything above $\frac{3}{4}$ in, which with the present speeds of gas-cutting would be very difficult to do. If, however, we have a heavy line, it can deal with any over-plus of light plates.

Mr **J. M. Borland** (Colvilles Ltd): Figure 2 shows alternative roll balance systems and Figs.5 and 6, two feed roller systems. In each case would the authors tell us what they recommend and the reasoning behind it? On the heavy shearing line in Fig.7 there are two cross-cutting shears beyond the side trimming shears. What is the reason for this?

At the earlier discussion I asked what blade angle on a conventional shear would give cutting results equivalent to the rocking blade shear. Would the authors please give their views on this point?

Mr **Sturdy:** The ideal chock is not shown in Fig.2. This is tied up with space and keeping the balance pressures down. We should try to keep the balance of the top chock pushing downwards. It really means a compromise between nos.3 and 4 in Fig.2. For the breast rollers we want individual drives; we want to get away from chains and gears wherever possible. Whether it is better to use spring mountings or solid mountings we have not yet enough experience to say, but we know that both work.

The blade angle on the rocking shear is 2°, rising to nearly 3° in the middle of the cut, which is about 1 in 28.

Mr **W. Craig** (Davy and United Engineering Co. Ltd): Two cross-cut shears are necessary to cope with the output of a modern plate plant. The first cross cut on the light line is to make a square end for entering the rotary trimmer.

Two cross-cut shears on the heavy line are installed to insure against any hold-up in production. Test pieces will be taken off on the first shear and a certain amount of preliminary cutting can also be done here. The second shear will cut to order. Alternatively, cut to length plates can be taken off at either shear as found convenient.

Mr **R. Jamieson** (Colvilles Ltd): In tests carried out with a conventional shear with a blade angle of 1 in 28 (2° 5′) we produced shear bow of something less than 1 in with various widths; the figures ranged from $\frac{1}{8}$ in to 1 in, and in all cases seemed less than the figures shown for the minimum with the rocking blade. Mr Sturdy referred to a range of 2–3° of cut angles, but during the action of the shear there is an almost static position of blade angle and I should like to know what that is. That may answer the original question of what is the blade angle.

Mr **Dowding:** The best plan would be to look at the figures produced by the people who designed the shears. The Schloemann shears at Appleby-Frodingham are of very much the same design. They say that the standard angle (the one now being asked for) throughout the cut is 3°. They argue that the shear bow is not a function of the angle at which the blade cuts but a function of the amount of overlap between the blades that occurs during the cut, and that is markedly smaller on the rocking blade shear than on the guillotine shear. I again appeal to anyone from Appleby-Frodingham, where both types have been used, to tell us what has been the effect of the change from one type to the other.

Mr **J. Dodd** (Appleby-Frodingham Steel Co.): I said at the earlier discussion that our experience with this type of shear was that we did not get much shear bow, but we did not get a large amount before that, except with the dolly shears, where we got a bow either on the scrap or on the piece, whichever was unsupported. I think that Mr Dowding has made a good point in saying that it is a question of the overlap or dip. With the conventional blade the dip is quite severe, perhaps 1 ft, but with this rocking blade I do not think that it goes down more than 2 in.

I have never understood that shear bow was the factor in making a decision between the conventional blade and the rocking type, and I am puzzled by the constant reference to the cost of this type of shear. I am not an engineer and I do not know the difference in cost between the two types; but I remember being taken two or three years ago to Genoa to see a rocking blade shear, and the visit was held to be justified by the fact that we could save about £20 000 because of the saving in connexion with the dipping table.

I should like to make some comments on the paper generally. In Table IV, for the two-stand four-high mill a better plate yield is shown with thick plate than with thin. Our experience is the reverse of this. As plate thickness increases, unless the slab weight can be increased it means shortening the plate and so decreasing the yield, because the same amount of end scrap is needed as on a longer plate.

In the typical layout shown in Fig.7 all the plates go across one cooling bed and after that are diverted into two streams, thick and thin. I should have thought that it would be better to take the thin plates from one bank and the thick from another or to divide the product by thickness at the mill and not at the cooling bank.

Most people when talking about scrap disposal think only of plate ends and so on, but even with the best steelmakers in the world there are times when whole plates have to go to scrap, and it often takes a long time to dispose of such plates with the scrap facilities provided.

On the question of flame cutting, we can now, with rotary blade shears, cut easily up to $\frac{3}{4}$ in. It is not possible to cut much over $1\frac{1}{4}$ in with a guillotine blade. I believe that work is being done to make it possible to cut up to 1 in with the rotary blade. If that can be done successfully, it may pay to do all plates above 1 in with flame cutting and do away with guillotine blades altogether.

On the question of the two sets of cross-cutting shears, I think the fact is that cross cutting takes longer than side cutting. We find that we need two cross cuts to keep one side shears going.

Mr **Dowding:** The overlap with a fixed rake blade having a 1 in 28 angle can, according to figures which I have here, be as high as 210 mm. On the rocking blade shear with the same width it would be between 90 and 120 mm. If that is the criterion of shear bow, the shear bow will be better with the rocking blade shear.

On the question of cost, for a heavy shear the weight of the rocking blade shear is 60–70% more than that of the straight blade shear and it is therefore more costly. I admit that I do not remember seeing a comparison of the whole installation, including the table, the electrical installation, and so on, and it may be that there is not much difference in the cost on that

basis, though I think that at one time we said that there was.

On the basis of the Appleby-Frodingham experience, those who have chosen to put in rocking blade shears are not going to regret it. What Mr Dodd has said emphasizes this.

The question of mill layout and the handling of plate in the finishing line I shall leave to Mr Sturdy. The point which has been made about the mill designers paying far more attention to the mill than to the finishing end would perhaps have been justified in the past, and some of the finishing ends we see around the world bear this out; they seem to have been left to fairly junior draughtsmen. We took a different view. When we got these first two large contracts for plate mills, including the finishing end, we appointed the most senior of our assistant chief engineers to handle the job, and a very good job he made of it. He brought to the problem experience of the design and layout of large slabbing mills, blooming mills, and section mills, usually with the accent on the mill, and he has made a very fine job of the finishing end.

Mr **Sturdy:** On the question of yield with thick and thin plates, the figures in our paper are actual figures from other plants, and the fact that they differ from other experience indicates differing conditions in differing plants. It does not necessarily follow that the plant with the highest yields is the most efficient. By dividing the plates after the mill you may be involving yourself in enormous extra capital cost to put down two sets of cooling beds each capable of handling the maximum lengths. In the particular case shown the output potential of the plant justified two cooling beds, so that we could have practised this if we wanted to do so.

With regard to the problem of disposing of a whole plate which is scrap it is not economical to build the scrap disposal system large enough to cater for this situation. However, these plates can be cut into shortish lengths and removed from the shear by magnet using a monorail crane built into the shears. These short lengths can then be reduced to scrap sizes at leisure. With rotary shears the limiting thickness is set by the amount of work-hardening on the plate edge. We have done experiments to get up to 1 in, but we have not been successful so far. We are still working on it.

Mr **R. B. Atkin** (Appleby-Frodingham Steel Co.): Comments have been asked for on the operation of the rocking shears, and the question of why the cross cut should be put ahead of the rotary shear has been asked. We have had experience of a 7-ft, and more recently of a 12-ft plate mill line. On the 7-ft plate mill line we did not have a cross-cut shear ahead of the rotary shear and in consequence we had a good deal of trouble. In commencing the edge cutting with the rotary shears the edge was such that we could not get our rotary shears to start to cut at all well, and we did a lot of nicking of the leading edge by flame cutting to get a square face for the rotary shear blade. That influenced us when we put down our 12-ft shearing line, and we put the cross-cut shear ahead of the rotary shear to present a square edge to it.

In our 12-ft line we find that we lose a certain amount of yield in cross cutting because of the position of the clampers. These are fixed too far away from the cutting line which results in excessive scrap losses at the leading end of the plate. This is something which can be overcome by redesigning the feed of the clampers. Mechanically we have had no trouble whatever.

Mr **D. Fraser** (Consett Iron Co. Ltd): In all our discussions on chock design, roll balance, and so on, the question of housing weight has arisen, and I believe the Davy and United Engineering Company have recommended a post area of between 1100 and 1200 in^2. We have received information that the Algoma Steel Corporation are producing highly satisfactory plates on a new mill with a housing post area of 750 in^2. Does this mean that we are building our housings much heavier than need be?

Mr **Dowding:** The mill at Algoma has an area of 750 in^2. It is a dual purpose mill, acting as a two-high slabbing mill one day and a four-high plate mill the next. It is producing a very good plate. Algoma are having to sell against the four-high mills of the Steel Company of Canada, so that they must be producing a product of good quality. I have always argued against the enormous increase in housing weight which has been inflicted on us by the Americans. The casting, however, does not cost very much compared with the all-up price of the plant. If within the casting weight one can get up to 1000 or 1100 in^2 on a plate mill, and one uses that metal in the right way to give the minimum stress in the housings and to accommodate the rolls in as narrow a window as possible, I believe that one will be able to get a closer tolerance on the plate than if something lighter is used. On strip mills I am not sure that this applies, but there one has the opportunity of using automatic gauge control, which is impossible on a plate mill because the piece is not in the bite long enough. I do not say that one is buying too much metal, but we were not limited in the design of our mill by the housing weight.

Algoma are thinking of having a separate plate mill eventually, because their output is going up, and they are asking for 1000–1100 in^2 for that.

Mr **R. G. Atkinson** (Dollery and Palmer Ltd): I feel that Mr Hanlon's question was not treated very seriously when he asked 'Is a cold plate leveller really necessary?' but I notice that in the typical plate mill layout in Fig.7 and in the discussion in the film there is no reference to cold plate levellers. Was this an oversight or can we assume that in the light of experience at various plants they are not necessary? There is a plate mill in Germany where the material arriving at the cold plate leveller is in an extremely flat condition and it seems that it is not essential to do any straightening work on it.

On the question of levellers, I should be interested to have some comments from the authors on the design of the levellers themselves, as regards the convergence of the levelling rollers. Should it be possible to send plates through the machine with the top and bottom nests of levelling rollers parallel, or would it be advisable to provide a tilting cradle for the bottom nest and individual vertical adjustment of the top set of rolls?

Mr **Dowding:** In dealing with the layouts we are discussing we did not mention cold levelling, perhaps owing to an oversight. I know that they come into the picture, and both South Durham and Consett have put a cold leveller or two cold levellers in their line in view of the increasing stringency regarding quality of plate which has been evident particularly during the recent slight recession in the plate trade.

With regard to the design of levellers, I would ask Mr Craig to say something about the hot leveller which was designed for South Durham. The others were bought from Head Wrightson.

Mr **W. Craig:** On the question of levellers, it is very difficult to get any accurate information on the advantages of keeping the top rollers at a parallel distance from the bottom, as against tilting the top rollers, but the general feeling among operators is that there is some advantage in tilting the top head, and most modern backed-up levellers are being built in this way. A good deal depends on whether the machine is being considered as a one-pass or as a three- or five-pass leveller, if, as frequently happens, the plate is not made level enough in the first pass.

I think that the whole aim of the designer of a leveller is to give the plate a good deformation between the first rollers and then to continue progressively until it finally emerges flat. If one asks any operator how he levels a plate it is surprising how little he can say about it, but many of them are very successful. In the design of a new machine I suggest that the top rollers should be made adjustable for tilting.

Mr **F. A. Batty** (The Head Wrightson Machine Co. Ltd): The choice of roll adjustment would be determined by the leveller duty required. If one-pass levelling is required so that plates can be fed through in a continuous flow, then a tilting adjustment for the rolls would be necessary. With this adjustment

the entry side would have a heavy setting easing off to a light setting at the exit side. With this type of setting the bulk of the work would be done by the rolls at the entry side of the machine. It has been found in practice that this type of roll setting is much less critical to slight differences in plate gauge than the reversing leveller where reliance is placed on the last roll at both entry and exit ends to take the curvature out of the plate put in by the heavy working of the rolls in the centre of the machine.

If a reversing duty is required, then a different type of roll adjustment is necessary so that identical settings can be obtained at both entry and exit ends to make it possible to run plates through and back without having to readjust the leveller for each pass. This type of leveller can have fewer rolls than the one-pass leveller and in this case the centre group of rolls would do the actual work on the plate and the last roll on both entry and exit sides would be adjustable in order to take out the curvature put into the plate by the centre rolls. In the case of the reversing leveller the centre rolls would have a parallel setting with the outer rolls set individually.

Mr **M. D. J. Brisby** (W. S. Atkins and Partners): The table in section 8 (p.490) of the paper suggests that for 750000 tons the mill layout should comprise a two-high rougher and a four-high finisher, but that for 1000000 tons two four-high stands should be used. Is it purely a question of output that decides which alternative should be adopted or does plate quality come into the picture? If money is available, should one have two four-high stands for 750000 tons, or one two-high and one four-high?

My second question concerns yield. We know that better yields can be obtained with four-high mills, but to what extent is the skill, science, or art of the mill manager, foreman, and operator responsible for high yields? Certain plate mills in this country and abroad get consistently better yields than others with very similar plant and equipment; there must therefore be something in the scheduling of operations and skill in marking out.

Thirdly, on finishing lines we know that there are several mills where output is restricted by the finishing capacity available. Can the authors give us any indication of the square feet of area of finishing line required per annual ton of product?

Mr **Thomas:** While a two-high roughing stand is cheaper than a four-high one it is more difficult to maintain excellent quality with it. That is one reason why the potential output of a two-high and four-high combination is lower than that of four-high and four-high, because an output limitation is imposed by having to draft the first stand to get a good shape of breakdown presented to the finishing stand.

Skilled scheduling has a big influence on yield but the plant itself is extremely important, and so are the orders. With good orders for fairly standard sizes which are easily scheduled the position is much easier than with small orders for difficult sizes such as shipbuilders still ask for. The yield problem is much more difficult with awkward orders, so that in addition to first-class equipment, skill and a good order book have a very important bearing indeed.

As regards area of finishing line, I have no figure in my head, but we have carried out studies which provide a great amount of data for calculations of this sort. The answer depends on a good many variables such as plate thickness, plate length, and size and quality produced, so that it is not easy to give a categorical reply.

Mr **J. H. Craig** (Colvilles Ltd): In Table IV a four-high mill was shown as having a yield of 80% whereas a combination of two-high and four-high gave a yield of between 81% and 83½%. Why should that be so?

Mr **Dowding:** A further answer to Mr Brisby's question of why yields vary so much from plant to plant may be that it is very often a function of the steel quality produced by that plant. It may go back to the steel practice and even to the iron practice. There are a good many very practical steelmakers present and I should like to hear their views on that.

In reply to the question on Table IV, the single four-high and the combination of two-high and four-high were in widely different plants. Probably any single-stand mill would have rather more difficulty in maintaining shape than a two-stand mill. The small difference in yield might be related to the shape of the finished product, which in one case might cause slightly more scrap somewhere down the line.

The **Chairman:** There are so many factors involved in yield that it is not possible to be dogmatic, and how it is possible to say that there is a yield which is the optimum yield if everything else is equal I do not know. I do not think it can be done. To take one simple factor, on most plates one has to have a length test cut off the plate, and that at once means that one has 18 in of scrap on the end, unless one can manage to get the test-piece on the side, and if one gets it on the side one has to have 3 in of side scrap, but with a really good modern mill one ought to be able to roll a plate properly and have only 1½ in of side scrap. There are all these factors to take into account.

Obviously, however, the four-high mill is bound to give a better yield, because there is not anything like so much lost weight in the centre of the plate as from a two-high mill. Whether there will be a better yield with a four-high mill or with two-high roughening and four-high finishing depends on all sorts of factors. It is difficult for a mill manager to get the rolls in two tandem mills to match up properly. He will not want to change his working rolls in the roughing mill as frequently as he changes the working rolls in the finishing mill, so that there is always a compromise between the best shape of plate coming out of the roughing and the best shape to put into the finishing.

All these factors affect yield, and I do not think that anyone could put his hand on his heart and say that x was the optimum yield. If one has the same 100% quality of steel coming from the steelworks into the slabbing mill, one can damage it in the slabbing mill or in the soaking pits or in the reheating furnace, and in fact everywhere along the line, so that one cannot say that the yield to be expected from a two-stand four-high mill is such-and-such. All that one can say is that the modern four-high mill, with the much better bearings than we had in the old days and with the much stiffer rolls and housings, is bound to have a much better potential yield.

Mr **R. A. Lake** (Richard Thomas and Baldwins Ltd): Elementary mechanics tells us that the best way to absorb impacts is to provide not only mass, but also a little movement. The people who make steam hammers do something of the kind to enable the anvil to meet the blow, but the people who make mill machinery still pin their faith to large lumps of rigid metal to absorb impact. I have no doubt that the mill housings are capable of doing so without damage, but in the case of live rollers it seems to me that the bearings have a thin time.

I should like to know how seriously this has been gone into. The only drawings shown seem to indicate a rather crude arrangement of springs such as are used in a railway wagon. Would not an annular spring, or possibly liquid spring around the bearings and interposed between it and the housing, be better? Is it impossible to make use of the properties of rubber? How far has an attempt been made to provide resilient mountings for these rollers? If nothing has been done, does it mean that there is so little bearing trouble that it is not worth the effort?

Mr **Sturdy:** We feel that springs are a very good answer to shock loading, but the trouble is that they cannot be introduced without introducing slots somewhere, and there must be sliding faces, and we land ourselves in just as much trouble in keeping the sliding faces in good shape and free from scale as in keeping the bearings in good shape on a solid mounting. The roller itself has some flexibility.

Mr **T. Harris** (Colvilles Ltd,): If I may pursue the vexed question of yields, I was surprised to read in section

16 of the paper that the authors regard edging rolls as 'an overrated luxury', and when rolling from slab to plate they estimated that an edger improved the yield by only ¼%. I should have put it at three or four times that figure, but, even if it is only ¼%, on an output of 500000 tons a year that is equivalent to about £75000. I do not know the capital and maintenance costs involved, but it would seem to be worth while to install edger rolls.

Mr **Dowding:** When we heard that people were going to order plate mills in this country we thought we should have a fine sale for edging mills, but when we tried to find the answers to expected inquiries we visited a dozen plants, with a questionnaire containing some 150 questions and we got a dozen completely different answers. We had to try to analyse the general views of practical men making plate with modern mills. We asked if an edger was necessary on the ingoing or outgoing side of a four-high plate mill, and the answer was that if rolling from slab one could not expect to get more than a ¼% improvement in yield and therefore the cost of an edger (which is quite expensive) was not justified. It is a question not only of the edger itself but of the foundation, the drive, the Ward–Leonard set, and so on. On the other hand, people rolling ingots said, 'If you have an ingot you must have an edger, because you have to square the ingot from its rhomboidal shape, and you get an improvement of between 3 and 4%.'

Some people who installed edgers on mills rolling from slab were persuaded to do so by our American competitors in Europe, and now say they have found them unnecessary in their practice. We have advised everybody, and we think they have adopted our advice, to leave provision for an edger in the layout, in case (*a*) they want to chase the odd ¼% yield and can afford to do it, or (*b*) they have to deal with steel qualities where edge treatment must be more fierce than it is on mild steel today, qualities such as stainless steels or titanium, where the edge may burst under the rolling load required by the reduction.

Mr **D. D. Ramsay** (Colvilles Ltd): Mention has been made of one or two operators, but at the present time most of us have three operators, the third operator being the roller, whose sole duty in most mills is to measure the width and thickness of the plate. Can the authors suggest any way of solving the problem of the automatic gauging of width and thickness?

Mr **Dowding:** On this question of instrumentation, we have a thickness meter and a width meter in operation in Canada. We have sometimes to go abroad to get our early efforts appreciated. We installed these at Algoma.

The width meter is installed fore and aft. It is in the roof trusses and measures the length of the plate after broadsiding. The only criticism is that when they want to change the width, the motors and the speeds we have installed make it too slow to move the heads in time for the next change. This is being put right. For the thickness gauge we have put in a gamma gauge which we built in conjunction with Isotopes Development. That has measured plate quite satisfactorily up to 2 in in thickness. The source is buried under the table between the rollers, with a lot of safety devices to ensure that no harm can come to the operators. There is a scintillation tube above the table. It is possible to measure the weight of the plate from the atomic weight, and therefore its thickness. That worked all right until it blew up. We expect this kind of thing with first-offs; our only difficulty is that we have to travel 3000 miles to put it right, so that we would prefer it to be just down the road, say at Appleby.

When these things are working they will be extremely valuable. It has always seemed to me ridiculous to put in an enormous four-high mill, where a man comes along with a stick and a bit of chalk to see what the width or the thickness is. We can assure Mr Ramsay that by the time the plant which he has in mind is going, it will be very modern with respect to measuring instruments.

WRITTEN CONTRIBUTION

Mr **H. R. Mills** (BISRA) wrote: I should like to ask the authors two questions relating to the section of their paper on finishing equipment.

The first question is about the turnover gear at the end of the cooling bank. Have the authors ever considered the desirability of siting the turnover arms not at the end of the cooling bank but at some distance before the end? The turning over of the plate is the first opportunity the inspector has of seeing the condition of the surface on the underside. If this surface is defective in any place, it may then be impossible to cut up the plate as originally planned. The inspector or the marker is then put in the position of having to make a quick decision; either the plate must be lifted from the bed and put aside to await further instructions, or it must be cut up in a way that is judged on the spot to be the best possible.

If, however, the inspection of the top surface of the plate and of its final dimensions were carried out some three or four plate widths before the end of the cooling bank and the turnover gear were situated at this point to turn the plate over, the inspection could be finished in time to allow for new instructions to be received about its cutting up if it were found to be defective, without the necessity of removing the plate from the flow line.

My second question relates to the removal of the scrap from the shears. I notice that the authors advocate scrap choppers and conveyors. A few years ago I saw in a German works, a very complete scrap chopping and conveyor system below the floor level of a plate mill. All the scrap, chopped into suitably small pieces, was fed on to a central conveyor which finally loaded it into the scrap boxes which were used by the open-hearth furnace.

As an engineering job, this seemed to me to be very fine and it had, of course, the advantage of avoiding any unnecessary handling, scrap boxes on bogies being filled at the exit from the plate-shearing bay. I was, however, more doubtful about the economics. The scrap conveyor system looked as though it would be expensive and it was difficult to know whether the cost of this would be justified by the avoidance of double handling later on. I should be glad to know the authors' views on the economics of scrap conveyors.

Mr **W. Craig:** We prefer to site the turnover gear about two plate widths from the end of the cooling bank. Mr Mills suggests three or four plate widths, but for economic reasons we find the cooling bank area is never sufficient and we must retain as much area as possible for cooling within the site limitations. Plates can be inspected on the bottom side and marked out to the best possible advantage, making allowance for any defective area of surface. Turnover gears must be made reversible so that the plates can be left with either side up and showing all the markings on the top surface.

The second question refers to scrap handling. An excellent example of mechanized scrap cutting, handling, and loading is now operating on our most recent plate mill plant. This equipment has now been operating for about three months and so far has been very successful, but we must wait a little longer before we can fully assess its many advantages.

Discussion on plate mill furnaces

The discussion at the third session was based on the paper **'Plate mill furnaces'**, by *The Society of Furnace Builders*, which was published in the March 1960 issue of the *Journal* (**194**, 365–383).

Mr **H. Southern** (President, The Society of Furnace Builders) presented the paper.

Mr **S. H. Brooks** (Appleby-Frodingham Steel Co.): I would like to begin by making some general comments.

Firstly, air infiltration. This is one of my principal enemies, and it can result in poor atmosphere control, reduced heat recovery, poor furnace pressure control, high exhaust fan power, etc.

The paper mentions our continuous bogie furnaces. Regenerative furnaces are notorious for leaking badly, and our original furnaces were no exception. The air infiltration expressed as a percentage of the wet waste gases leaving the furnace chamber (and hence including bogie seal infiltration) was no less than 60% on the acceptance test of one of our old furnaces.

When we installed our new bogie furnaces a short time ago, some improvements were made as detailed in the paper, but the one to which I wish to draw attention is that the regenerators were completely plated, right from the sand seal on the inside to the furnace casing on the outside; the plating included even the collecting flue and the regenerator base. We have just carried out a test on one furnace and the infiltration was only 14½% (up to the recuperator inlet) as compared with the previous figure mentioned of 60% leaving the checkers.

We think this is important and we have applied the same principle, of having nothing but metal to metal joints, to other furnaces. For instance, our original one-way recuperative soaking pits were constructed conventionally with steel casing, steel flue, short brick elbow, and steel recuperators. The infiltration was 13% of the waste gas volume; and after a period of use became much worse. On the newer pits the brick elbow was cased so that we had metal to metal joints right through and the recuperator design was modified to prevent infiltration and a test has shown a figure of only 6% which can be reckoned to be nearly perfect.

This principle is also applied to the Ajax steel furnaces where the port ends, uptakes, slag pockets, and regenerators are continuously steel encased. On the furnace being currently converted to Ajax the whole flue is cased and bolted up to the waste heat boiler inlet box.

I think most steelmakers will agree that this is a sound principle; if not from the technical aspect, they must agree that it is good for the plate business!

End discharge pusher furnaces are mentioned in the paper, and these are notoriously difficult to keep infiltration-free in the furnace chamber itself. The discharge ramp acts as an efficient chimney to induce cold air. I know of one such furnace where all the air can be turned off the soak zone burners and auxiliary gas burners used and still give substantial quantities of oxygen in the atmosphere. This is a particularly serious disadvantage of this type of furnace, and I note that the furnace builders have recognized this by firing one furnace towards the doors. This should be an improvement, and I would like to know whether all the difficulties are overcome by this means and whether other methods are now available.

And now for fans. We have tended in the past to look upon the fans as an unimportant item. While this attitude may be excusable on small furnaces, it is certainly not so on the large ones we are considering today, where fan power (particularly of induced draught fans) may be over 100 hp.

The use of low-efficiency fans is usually false economy. We have found that the extra cost of a high efficiency fan is recovered by power saving in only one or two years. Too often low efficiency fans are defended for use on exhaust duty because the paddle-bladed type is considered appropriate for flue gases. There may be a case for this with dirty gases, though I doubt it, but no case at all with furnaces fired by clean gaseous fuels or oil. The only exception to the rule that higher efficiency fans pay, was the case of a high-temperature induced draught fan where special materials made the cost increase uneconomic.

I would like to speak on fan control. The old-fashioned butterfly or sliding damper which wastes power when not fully open is almost universal and consideration ought to be given to the more refined methods. Variable speed control is theoretically the best, but is costly and presents more control difficulties due to the inertia of the fan. Nearly as good, however, is inlet vane control, and this ought to be fitted on all the larger fans, particularly where a wide turn-down range is used as on modern soakers. Our soakers do not have this feature, but the new bogie reheaters and OH furnace induced draught fans are so equipped.

I next want to speak about heat recovery, if only because of a statement that 'when it is possible to dispense with the use of recuperators, waste heat boilers are often installed'. This implies that recuperators are only used in preference to waste heat boilers where their use is necessary due to the high temperature needed or the leanness of the gas. This is not always so. If we consider a furnace exhausting at 1300°C and fired by coke oven gas, the use of a recuperator giving 700°C air preheat will give a fuel saving of 1·6 times the amount of heat in the air. This is a far better ratio than can be offered by steam raising where the ratio between fuel saved and heat extracted is of the order of 1·3:1. In this particular example the waste gas would leave the recuperator, assuming no dilution and heat loss, at over 800°C and a waste heat boiler would, of course, have recovered more of the heat, down to say 250°C, but the ideal thermal combination would have been a recuperator followed by a waste heat boiler.

The advantage of recuperation diminishes with lower exhaust temperatures and increases when leaner fuels are used. Each case should be examined on its own merits, but it should be appreciated that waste heat boilers can often give a lower fuel saving for a given heat return than recuperators.

Now I would like to comment on the furnaces mentioned in the paper of which I have some experience. First, electric soakers. A recent paper has described how we use our single electrode pit for cooling or conditioning short track time ingots. I would merely confirm that this unit has given us good service and consumes only about 1 therm/ton at 2000 tons/week. It we had enough hot steel at the right time it would consume no electricity at all.

I would like to mention, however, our gas-fired controlled cooling pit. This is similar to the electric pit but each cell is completely separate and has a small coke oven gas burner to keep the cell hot when empty. This burner is turned off just before charging a hot ingot. In other words, it is used in precisely the same way as the electric pit. At throughputs of 1300 tons/week fuel consumption is 4½ therms/ton. This compares with 1·6 therms/ton on the electric pit at similar throughput rates. Based on fuel costs of 2/6 per therm for electricity and 6*d*. per therm for gas, it will be seen that the gas-fired unit has fuel costs some 44% cheaper. It is expected that maintenance costs will be even lower than the electric pit and capital cost is only about two-thirds of that unit.

I have already referred to our new slab reheaters, and it may make the account complete if I refer to some recent test figures obtained with blast-furnace gas of 95 Btu/ft³ calorific value rather than the specified mixed gas. Output was 13·9 tons/h and fuel consumption was 24·4 therms/ton. These are not quite so optimistic as the figures quoted in the paper, but are very creditable on a furnace designed for fuel of 160 Btu/ft³. We fully expect the performance to be better than guarantee when the specified fuel is used.

I would like to quote some test figures for the continuous normalizing furnace mentioned in the paper. For a throughput of 40 tons/h heating from 618 to 860°C the fuel consumption was 6·2 therms/ton. Long-term fuel consumption runs between 7 and 8 therms/ton, and I would be surprised if the figure of 15 therms/ton mentioned for cold plates could not be substantially bettered. Air infiltration was 16½% of the wet waste gas leaving the furnace chamber, and can be considered to be reasonable, if not quite up to our high standards.

The batch normalizer mentioned has been tested heating cold plate to 900°C for 16·8 therms/ton. Air infiltration was of the same order as for the continuous furnace: 14% at recuperator exit.

The main snags with the double roof type of construction are (*a*) that it is impossible in our experience to work with excess air at less than 25%, and this is not particularly good with gaseous fuels. (*b*) It is difficult to keep the space tight and combustion air can be lost by leakage; about 20 to 30% loss of the fan air has been observed, and apart from causing reduced effective preheat, air/gas ratio control is made more difficult.

It must be admitted that the flames produced by this system seem ideal for normalizing, but I would like similar

results to be obtained without loss of air and with reduced excess air in the furnace. Am I asking for the impossible? I do not think so.

I hope that these comments have been of interest and will help, if held is needed, to provoke a good discussion. May I finish by saying that a target of 18 to 20 therms/ton for slab reheating is, in my opinion, too high. I see no reason why 16 or even 14 therms/ton should not be possible if attention is paid to some of the factors I have mentioned and to others that are no doubt on the drawing boards of the firms concerned.

Mr **Southern:** I wish to thank Mr Brooks for opening the discussion in such a broad and interesting manner. He has referred to most of the furnaces described in the paper, drawn particular attention to factors which influence their performance, and spoken, from his wide experience, on the operation of furnaces in general.

His timely remarks on the subject of air infiltration are fully endorsed.

In furnace practice the attainment of optimum conditions of operation largely depends upon the minimization of air infiltration and this can certainly be achieved by completely encasing the brickwork in steel plates. The benefits obtained are lasting, and, as clearly indicated by Mr Brooks, outweigh the extra expenditure involved.

In the present era of exacting production requirements and rising fuel prices it is imperative to employ furnaces which are in every respect suitable for the efficient performance of the specific duties likely to be imposed upon them. Such furnaces can seldom be bought cheaply because they must have the necessary mechanical and structural features to ensure trouble-free life, be thermally balanced and suitably constructed for the easy attainment of optimum conditions of operation and be automatically controlled for the regular day to day maintenance of those conditions.

The drastic limitation of expenditure during the purchase of furnaces is not conducive to the installation of units of the best available type and the main consideration at the time of selection should always be 'what irrecoverable benefits and savings will be lost if such a policy is pursued'.

Mr **A. Kilby** (Priest Furnaces Ltd): Mr Southern has made some true and relevant remarks about the initial expenditure particularly on furnaces of this magnitude. There is always a time, when one is quoting for furnaces of this size, when there is a question of price. Mr Brooks has shown that with a comparatively small expenditure, plus the fact that it was possible to use a little more steel plate at a time when one could not sell steel plate, quite a big return was obtained.

The difference in the performance of the two furnaces is quite easily seen in this particular instance, and I feel that this is a startling case for spending a little extra money to get a good return.

The question of high efficiency fans also comes within the category of the remarks I have just made. It is a more expensive unit, but it does give some return for the extra capital expenditure.

The question of air infiltration on the multi-zone furnaces is a serious one. This has been tackled in a number of ways, and one way mentioned in the paper is the reverse firing. There are other suggestions for rows of burners at the discharge end to take care of the natural draughting of the furnace. I think that it is only if some of these methods were given more trial that we should get the answer.

Mr **Southern:** Air infiltration at the discharge slopes of multi-zone continuous furnaces has been mentioned. The paper describes furnaces of the normal type in which the soaking zones are end-fired and also one of Continental design in which the soaking zone is fired in the reverse direction. Perhaps this is a subject upon which Mr Williams may wish to comment.

Mr **C. H. Williams** (Stein and Atkinson Ltd): The air infiltration at the soaking end of a continuous furnace may at certain times be up to 30% of the theoretical air required for combustion in the soaking zone, but when one recalls that the soak zone uses only about ¼ of the total fuel used on the furnace, this air infiltration is not important, and it is a fact that this occurs on virtually every strip mill furnace in the world, yet both economy and surface finish are satisfactory. Nevertheless, do not let me convey to you the idea that this is something we are satisfied with. We, along with our associate companies, are at the present moment working on means for effectively reducing this. We installed eductors in the discharge slope of the soaking zone hearth some time ago, but the trouble here was the question of maintenance. Even so, they are still used and still favoured by a number of our customers, although they cost more.

Reverse firing has been tried out not only on the Continent but in America quite a number of years ago on an important and well-known installation, but it was not proceeded with elsewhere. I have seen this and our associates are also familiar with this installation. I have only recently heard of it being used elsewhere.

Mr Brooks' reference to the electric pit at Appleby-Frodingham was interesting, as was also his comparison with the gas-fired cooling pits. I think that, in regard to the electric pit, it should be recalled that when their pit was designed it was essentially for Appleby-Frodingham hot ingot conditions only, and with a very small electric input. In this respect it is quite different from virtually all the electric pits which have since been built. The limitation in heating capacity was quite deliberate and, moreover, the design was better suited to the restricted site.

The advantage of heating ingots with a much wider range of charging temperatures with the more conventional higher input electric pit is now widely established and it is as well that this is not forgotten: such flexibility is, under normal mill conditions, a usual requirement.

Mr **G. Harrison** (Gibbons Bros.): Mr Brooks mentioned inducing air at the discharge end, the chimney effect of the discharge slope, and the fact that reverse firing had been employed, and went on to say that there are two different schools of thought on this subject. I was very interested in his remarks, and his statement that he would like to hear the views of users having experience of reverse firing.

There are a number of reheating furnaces on the Continent with reverse firing that are working extremely well, but we do know from experience that the actual profile of the soaking zone roof is of vital importance if it is to be a success. With certain roof profiles, reverse firing has not always proved as good as one would have liked.

In this connexion, it would seem that, so far as the design of furnaces is concerned, there is a great deal of scope for some research on this question. About three weeks ago I saw two furnaces on the Continent, each with an output of 80 tons/h, and embodying reverse firing. They were working extremely well, and the customer was very satisfied. I also saw one working in Berlin, and there were two members of one of the largest steel organizations in this country present at the same time, who passed the remark that they were very surprised indeed at the comparatively small amount of scale on the billets that were being discharged from the furnace. There is no doubt at all that, subject to the profile of the roof being designed properly, there is something to be said for reverse firing in the matter of keeping the scale losses down.

On the question of the induced draught fan and saving power, it is true that the butterfly damper in many respects leaves a lot to be desired. I think that more of the induced draught fans on large slab reheating furnaces should be fitted with a fluid drive or scoop coupling. With this method, there is a saving in electrical power when the furnace is working below its maximum consumption; but here we come up against the problem mentioned by Mr Kilby, that whatever the furnace designer or supplier might like to do, he is always faced with extreme competition, and this is a more expensive way of draughting a furnace.

I would also like to comment on what Mr Brooks said about their experience of the continuous normalizing furnace installed in their works. The therms per ton of metal heated

that are given are on the basis of a cold charge. At Appleby-Frodingham very rarely do they place a cold charge in the furnace and that is the reason why the actual therms per ton are considerably less. We have given the figures of the original tests made on the furnace, and I have no doubt that since 1953 or 1954, when the tests were made, the figures now show up very much better than we were able to achieve at the time; nevertheless we based our consumption on a cold charge, whereas invariably the charge is at 600°C, and if our figure was related to a hot charge it would be brought down to something of the order that Mr Brooks stated.

On the batch type normalizing furnace there is a definite problem with regard to air leakage, and during Mr Brooks' remarks I was thinking that it might be possible to encase the upper chamber which acts as the air reservoir, or, alternatively perhaps, a better way would be to go from the sprung arch to a flat suspended roof at that point. This would give a better chance of sealing as against the sprung arch, with its inherent possibility of opening of joints after a continuous period of working.

With reference to recuperators and waste heat boilers, in a paper given at the Staffordshire Iron and Steel Institute last week the point was made that there is no reason whatever why both recuperators and waste heat boilers should not be embodied in the same system; and to some extent this has been accomplished, for when we look at the pair of furnaces shown on p.371, Fig.7, the triple-zone continuous slab reheating furnaces, we see that recuperation is applied, and although a waste heat boiler is not embodied in the system, there is evaporative cooling which can be considered its equivalent. These are Continental furnaces, and I think I am right in saying that there are no reheating furnaces in Britain that have evaporative cooling, although I fancy that there will be some in the very near future.

Mr **A. Marshall** (Consett Iron Co. Ltd): I should like to ask the various contributors to this paper, or anyone who may have batch furnaces in operation, to comment on the troubles they have had with the wearing plates in the furnace for the charger runners. At Consett we have adapted an existing furnace for this type of machine, and we have ended up with bad results due to rolling or coiling of the wearing plates after breaking. I know that the manufacturers are working on this problem, but I should like to hear comments from other people who may have had this trouble.

Mr **Harrison:** We are well aware of the problem that Mr Marshall has outlined concerning the bottom of the charging arm track. Incidentally, our furnace at Consett is working, or it was said to be suitable for working, at a lower temperature than the one installed at Appleby-Frodingham. Appleby-Frodingham are usually operating with commercial steel, normalizing around 930–950°C, but they do normalize also at 1 080°C when they place stainless steel in the furnace.

Metallic tracks have not been a success for the special type heavy charging machine used for large batch normalizing furnaces for stainless steel. The Appleby-Frodingham machine which was specially designed and intended to take a 12-ton load, has proved this conclusively. Our company has carried out considerable research and have now put into operation on the furnaces at Appleby-Frodingham a refractory block which is giving a greater life than the metallic strip that was used previously. There is still room for some improvement with regard to these track blocks, but we do find in practice that the wear towards the back of the furnace is not very great, and the wear at the charge end, the first 6 to 8 ft out of the 45 ft length, is considerably less than when metal is used for the bottom of the track. On all future furnaces of this type we would definitely use the special refractory material that we have developed during the last 12 to 18 months.

Mr **D. D. Ramsay** (Colvilles Ltd): It has been mentioned today that the pusher type furnace can heat up to 12 in thick. Mr Marshall in his paper, was emphatic that 10 in was the limit. Can the furnace builders assure us that they can heat at 12 in, or is Mr Marshall's figure correct?

Also with regard to the pusher type furnaces, are ceramic shrouds definitely successful on the bearers in pusher type furnaces, or do we still need to trust to the water or steam cooled skids? Further, is there any limit to the length of steel which can be pushed, in other words, the length of the furnace, or does this depend on the thickness of the material being pushed?

Finally, in connexion with rotary furnaces, can anyone give information on the following point: although the atmosphere should be controlled to avoid forming scale, we know that if the mill is off for some hours it is almost inevitable that scale will form. How will this scale or cinder be removed from the furnace?

Mr **C. L. A. Webb** (Stein and Atkinson): Mr Marshall mentioned 10-in thick slabs, but the first two plate slab-heating furnaces of the continuous type put in at Consett were actually designed for 14-in maximum. We do know that it is a difficult problem to heat much over 10-in, but it is done, although of course, at slower rates of heating.

On the question of skid insulation, we feel that there is a great deal of work yet to be accomplished and that one day we are going to find a satisfactory solution to this; it depends to some extent on how far evaporative cooling goes in as well. Undoubtedly steam recovery in many places is of great value; at other plants it may not be so important, and insulation must be the answer to this very heavy Btu loss through water cooling. With the amount of work being done on skid insulation, one feels that, as with so many other problems, we shall be getting better results soon.

On the question of length of push, there are limits to how far one can push, particularly in the case of thin slabs. What those limits are at the moment it is a little difficult to say, because every time we get one of these new mills to consider, we find that a greater distance between the pusher head and the discharge apex is asked for.

It is a question each time of weighing up a whole number of factors, and it is not possible therefore to give a plain straightforward answer.

Mr **Kilby:** On the question of thickness of the slab which can be pushed, we have definitely done 12 in on a multi-zone furnace, and we are happy with that. We have seen cases on the Continent where they have gone above 12 in without trouble. We have no doubt that it is possible to heat thicker slabs than 12 in but for comfort we think that 12 in is a reasonable figure.

As Mr Webb stated, the length of push that one can undertake depends on a number of factors, not least of which is the question of round corners on the slab in question, the difference in thickness, etc. We think that another factor which plays a part is the type of pusher used. We have found that the hydraulic pusher definitely has an advantage in this respect, that with the electric pusher one does not get the same gentle take-up that one does with the hydraulic pusher. So far as we can see, 100 ft is quite a commonplace push now, and whether that is the limit or not is doubtful.

Mr **Marshall:** On the question of slab thickness, I agree that at Consett 16-in slabs are going through the slab furnaces, but all slabs over 10 in in the Consett furnaces are only taken up to a temperature of about 950°C and are then removed from the continuous furnaces and put into wash heat furnaces for final heating. We had to do this in the early stages when we kept three or four small furnaces going.

I would like to comment on the 10-in figure given yesterday in the paper which I presented. That 10-in figure was arrived at after studying plants all over the world. We found that in numerous cases people who had put in continuous furnaces for slabs up to 12 or 14 in thick found that they had so much difficulty with edge welding on the thick slabs that they had to resort to putting in some other type of heating for the thicker slabs. That is why we decided on 10 in. It is a matter of opinion and of finding out in one's own practice in one's own furnace.

Mr **J. Dodd** (Appleby-Frodingham Steel Company): On the question of slab thickness, all the speakers have talked about the maximum, but have not given the limits of variation between minimum and maximum. Will one of the furnace builders give us the range of slab thickness which can be accommodated in one furnace?

Mr **Harrison:** Dealing first with Mr Marshall's point about the thickness, we are reasonably satisfied that one can go up to 12 in thick and even above in certain cases. The difficulty that he has raised with regard to the welding of the edges of the slabs stems from the design of the furnace in respect of its length. The Continental practice is to design the length of the furnace on the basis of a 50°C differential between the outside of the slab and the core. In the USA and UK we do it a little bit differently. The mills are usually designed with plenty of power, and if there is a 100°C differential it does not matter very much; but when we have a thick slab which has 100°C or 125°C differential, it means that if the core is going to be at a suitable temperature for good rolling the outside temperature of the slab is going up to 1300–1325°C and temperatures of that order. That is when we are likely to get sticking at the edges.

With regard to Mr Dodd's point on pushing length and thickness, I would say that the answer there is in the initial design; that it is the thinnest slab that is being heated that determines the length. As Mr Kilby has said, a lot depends, in connexion with the maximum length of furnace for pushing slabs, on the edge itself. If we have a truly square edge, there is a certain figure that can be taken with reasonable safety, but once we depart from a truly rectilinear section, we must shorten the furnace if 'piling' is to be avoided. But really the length of any pushing furnace should be first of all determined on the basis of the thinnest slab that is going to be heated, and then one must work back to the output that is possible with the thickest slab.

Perhaps I might try to reply to the point that was raised with regard to rotary hearth furnaces. We have had no experience of trouble with slagging on the hearth of a rotary hearth furance, and in fact the first one that we built in this country had no hearth repairs for the first two years.

Our normal practice on mill shutdown is to turn out some of the burners, and if the mill delay is of a long duration, we reverse the hearth and bring the slabs back out of the hottest zone. With regard to the falling of scale on to the hearth, of course there is an advantage on the rotary hearth furnace in that there is no relative movement between slab and slab or slab and hearth, and as the slabs are picked up vertically without any dragging, there is no tendency for the scale to become detached from the slab.

With reference to the problem of heating thick slabs, we are heating 9 in thick slabs for rolling quite satisfactorily at a rate of about 28 min/in on a rotary hearth furnace.

Mr **J. H. Flux** (The United Steel Companies Ltd): Reference has been made to evaporative cooling, and it might be useful to record that at the Steel Peech and Tozer works evaporative cooling has been in use for just over 12 months on an OH furnace, where it is working exceedingly well. However, the use of evaporative cooling on reheating furnaces should be treated with a little reserve. Mr Brooks has already pointed out the thermal advantage, although only marginal, of a recuperator designed to give the maximum return in air preheat and reduced fuel consumption. The modern recuperator is effective and so designed that it requires no additional furnace supervision. Evaporative cooling with a waste heat boiler attached to a re-heating furnace on the other hand will demand extra labour in the form of a boiler attendant. With a number of OH furnaces in one melting shop the cost of this supervision is proportionately reduced, but if one attendant is required to look after the evaporative cooling on one reheating furnace the cost of the steam becomes rather high, and the return on capital is not so attractive.

As far as possible the reheating furnace should become a self-contained unit and, instead of replacing inefficient water-cooling with reliable evaporative cooling, the use of cooled skids should, if possible, be dispensed with. It is very desirable that attention should be directed towards the development of satisfactory dry skid material using evaporative cooling only in the last resort, bearing in mind that for a small reheating furnace in an isolated situation and requiring additional attendants, it is not an economic way of steam raising. It is merely a good method of overcoming difficulties resulting from poor quality water cooling.

Mr **Williams:** I should like to comment against Mr Flux's remarks on evaporative cooling on continuous furnace skid systems. I am in complete agreement with him, of course, on the question of OH furnaces.

As regards the skid system, one major feature which has been demonstrated is that, as a result of evaporative cooling, a greater reliability of the skid system is achieved due to the circulation of boiler feed water. This, of course, leads to a greater furnace availability.

In regard to his point about attendants, I have visited a plant in Düsseldorf, which has over 40 hot cooling installations on furnaces of many types. These operate at low pressure, and continuous attendance is apparently not necessary. For the more usual high pressure installations there must be some way of overcoming the problem of manning, since the advantages, both from the economic point of view and the reliability point of view, are very great.

Mr **Flux:** I would confirm Mr Williams' remarks by saying that in our experience evaporative cooling is thermally and mechanically very efficient and as a means of reducing maintenance on skids in reheating furnaces I would expect it to be very effective.

Nevertheless, its use on reheating furnaces may well require the introduction of additional labour making the economics less attractive. Each installation will require separate consideration but the advent of evaporative cooling should not preclude the further development of dry skid material.

Mr **M. D. J. Brisby** (W. S. Atkins and Partners): Some time back we studied the economics of electric and conventional soaking pits. There are certain interesting factors which come into the picture. These are:

(i) the price of electricity: unfortunately, we can do little to reduce this in our country
(ii) the temperature at which ingots are charged to the soaking pit: we *can* do something about this, namely reduce track times and schedule soaking pit operation. Electric soaking pits become a really attractive proposition if they are used with hot ingots
(iii) the quantity of scale that can be saved by using electric soaking pits.

On this last point we consulted several mill managers who felt that they wanted 1½–2% scale in order to roll a good slab. However, at least one mill manager felt that this was excessive and that provided ingot moulds were sound and that a good clean ingot was cast, no more than ¾–1% scale was needed for surface cleaning when slabbing. If a reduction in scale of 1%, say from 2% down to 1%, was acceptable, then the benefits of electric soaking pits become very apparent. I have seen ingots rolled at one works in Austria where they consistently operate with only ¼% scale loss and the slabs produced were sound.

I should be most interested to hear the author's views on the question of scale when slabbing ingots. In our study we were able to calculate break even figures which took into account the variation in ingot temperatures and the quantity of scale produced. We showed our results to various mill managers who agreed broadly with our findings. Briefly, our conclusions were that electric soaking pits were an attractive proposition provided they were charged with hot ingots and that the mill operators were prepared to accept low scaling on the ingots.

Mr **Dodd:** I cannot remember the occasion referred to, but I am in complete agreement with Mr Brisby. As has been said, the electric soaking pit that we have is used for ingots with a

very short track time. It is a cooling rather than a heating pit. When we first had it, I think it is true to say that we did not get anything like ½% scale. The ingots came out of the pit looking exactly as they were when they went in. We had to introduce a little air to take off some of the surface defects.

The **Chairman:** I should like to mention that our experience with the electric soaking pit has been the same; we had to introduce a little air in order to have a little scaling. I think that this does raise a point of which we should not lose sight. Although it is very nice to have as low a fuel cost as possible on any furnace – fuel is obviously a very costly thing in a steelworks – we must remember that the primary objective of all these furnaces is to heat steel, and that is the thing that we must always look to first: to heat steel quickly enough for the production required in any mill and also, of course, to heat it in such a way that we get the best possible steel. Although we also like to have all these other advantages, such as raising steam, we do not want to put in our furnaces primarily as boilers, but to provide a good steel product.

As I mentioned yesterday, one of the difficulties that we are up against in an integrated steelworks is this steam problem. With the changeover from the conventional methods of making steel to the new methods of oxygen steelmaking, we are going to be up against a difficulty of steam, and indeed a fuel and power balance in an integrated works very different from what it has been. I think we shall find that we are probably going to have surplus gas that we did not anticipate, and also we may find that we have surplus steam. Therefore, although it may be very nice to raise steam from any heating furnace, unless a works has some use for that steam, the gain may be more apparent than real.

These are problems which are becoming so important that we have thought in the Engineers Group that we ought to have a meeting in the near future at which all these problems connected with the new processes could be ventilated. I do not mean the process itself, but all the ancillary things connected with it, such as gas, steam, and power balance.

Mr **R. Jamieson** (Colvilles Ltd): Some work has been done on the Continent, in furnaces working at lower temperatures, on ceramic skids. Could the furnace builders indicate what future there is for ceramic skids, and what work, if any, is being done on them in the UK?

Mr **Harrison:** Ceramic skids are being accepted in a certain type of furnace installed on the Continent. There is no doubt that the ceramic skid improves the overall thermal efficiency, because there are not the same heat losses. One firm in this country has had trials in an existing furnace with a ceramic skid that was bought from France, and, according to my information, it looks like being a pronounced advantage over the water-cooled skid.

Work and research is being carried on at the present time on the use of ceramic skids, and I think that perhaps within the next two or three years, on shorter furnaces for heating slabs and billets, there will be an increased use of ceramic skids instead of water-cooled skids.

There is one furnace which has just been put into commission in this country, a complete furnace, which is fitted with ceramic skids, and it is heating billets up to about 8 in square at the rate of 10 tons/h.

Mr **E. F. Fowler** (Stein and Atkinson Ltd): May I ask Mr Harrison whether the furnaces they have installed, using ceramic skids, are underfired?

Mr **Harrison:** Yes, top and bottom fired.

The **Chairman:** If there are no further comments or questions I will ask Mr Southern to wind up the discussion.

Mr **Southern:** I do not propose to speak as President of the Society of Furnace Builders but rather as a student of furnace technology.

Mr Brooks referred to the consumption of fuel in furnaces and cited several figures from the text of the paper. May I add that these figures are the results obtained in practice. They are not target figures.

Mr Brooks continued to say that he sees no reason why it should not be possible to raise cold steel to rolling temperature on a consumption of 16 therms/ton. I entirely agree with him provided the use of continuous reheating furnaces is presupposed.

The heat absorbed by 1 ton of steel when raised from cold to rolling temperature is about 800000 Btu or 8 therms/ton. To do the job in the practical field on a consumption of 16 therms/ton simply means the proper use of furnaces capable of operating at an overall thermal efficiency of 50%. Many top-fired continuous furnaces of limited capacity, without water-cooled skids, attain this degree of efficiency in daily operation.

The true thermal efficiency of the heating or melting chamber of a furnace, as distinct from the related overall efficiency of the furnace, depends upon two factors which concern the distribution of heat within it. One is the factor of heat availability and the other the factor of heat utilization. The first is the ratio between the heat available for use within the chamber and the total heat input to the chamber. The second is the ratio between the heat absorbed by the charge and the heat available for use within the chamber. The product of the two factors is the ratio between the heat absorbed by the charge and the total heat input to the chamber and this indicates the true thermal efficiency of the chamber.

If the heat content of the exhaust gases at the outlet ports of a simple continuous furnace is 37·5% of the total heat input at the firing end then 62·5% of the input is available to heat the charge and balance the chamber losses. The factor of heat availability is therefore 0·625.

Now if 80% of the available heat is actually absorbed by the charge then the factor of heat utilization is 0·8 and the true thermal efficiency of the furnace chamber is $0{\cdot}625 \times 0{\cdot}8 = 0{\cdot}5 = 50\%$.

This example shows that a furnace operates at high efficiency only when the product of the factors of heat availability and heat utilization is high.

In large continuous reheating furnaces of the multi-zone type the use of water-cooled skids and supports is necessitated by practical requirements, but the thermal losses which directly arise from water cooling frequently exceed the total losses from the walls and doors of the chambers. As a result much of the heat available for effective use is dissipated and the factor of heat utilization is lower than desired.

Attempts have been made, with varying degrees of success, to shroud the skids and supports and thus to reduce the cooling losses but the practical problems which arise are difficult to combat.

The complete elimination of water-cooling is of course the desired end but it is as yet too early to say what success will attend the development and use of dry refractory skids. In some installations their application is promising.

Evaporative cooling is undoubtedly effective in the recovery of the heat normally dissipated by water-cooled skids but it is not the complete answer to the problem. Although the heat is substantially regained it cannot be used within the furnace chamber therefore the factors of heat availability and heat utilization are not improved. Even so the system is conducive to considerable economic gain provided the steam produced can be utilized elsewhere. That is not always possible as the Chairman has indicated.

The question of slab thickness and its effect upon the time and quality of heating has been raised. This is a subject which cannot be adequately considered or discussed in the limited time available.

Many factors influence the rate at which billets, blooms, and slabs of different thicknesses can be satisfactorily heated and the overriding one is the permissible temperature differential within the stock at the point of discharge. This greatly affects the heating time.

In a very general manner it may be stated that top fired furnaces satisfactorily heat stock up to a thickness of 5 in. Beyond that thickness, top and bottom fired furnaces are

desirable. In furnaces of this type the heating of stock up to a thickness of 8 in presents no problems and the rate and quality of heating are satisfactory. With stock thicker than 8 in the vital relationship between heating time and temperature differential becomes increasingly apparent.

The rate at which the stock can then be satisfactorily heated depends upon two factors: the degree of temperature uniformity required and the avoidance of 'sticking' before that uniformity is achieved.

Before the conclusion of the session I should like to thank all present for their interest in the paper and also to acknowledge the collaboration and great help which I have received, during both its compilation and presentation, from various members of the Society of Furnace Builders.

Discussion on electrical equipment for reversing plate mills

The discussion at the final session was based on the paper **'Developments in electrical equipment for reversing plate mills'**, by *H. S. Brown* and *A. P. Baines*, which appeared in the February 1960 issue of the *Journal* (**194**, 225–240). Mr Brown (The English Electric Company Ltd, Stafford) presented the paper.

Mr **G. Ovens** (McLellan and Partners): The authors are to be complimented on producing a paper of interest to a much wider field than that concerned with the design of electrical equipment for plate mills. Motor ratings, supplies for variable voltage drives, particularly those for reversing duty, servo-controls of auxiliaries, and automatic methods, are of fundamental interest to all in the iron and steel industry. The application of electrical equipment to a reversing plate mill is an excellent way of bringing many aspects together for general survey and discussion. I therefore like the range of the paper and I feel sure that all of us will find some parts of it of more than general interest. Looking at the paper generally, I have only one serious adverse criticism; there are only seven references given. Of these, four are dispensed with in the second paragraph and cover the history of the art of motor rating up to the time the authors take up the story. The references peter out less than one-fifth of the way through, long before that part of the paper dealing with automatic controls and particularly the section on position control servos on which so much work has been done in service applications and in many industries other than our own. So much has been written on servos that I should have expected that the authors would have been able to choose some apt source of support in their dealings with the difficulties that arise from stiction and backlash. Furthermore, references to papers published in the *Journal*, covering BISRA's work on position control, programme control, and translator methods surely would have been appropriate. References such as these in other parts of the paper would have enhanced the value of what is undoubtedly a good integrating paper combining many aspects of application engineering.

When dealing with motor rating, particularly in the context of rms torques and duty cycles, too general use of the word 'maximum' may be misleading. This applies to the definitions given in the paper where the word 'greatest' would be better in most instances, leaving maximum to be used for quantities, such as working torque, which vary up to a maximum in cyclic duty.

In common with many other applications, the problems of finding some yardstick for motor rating are exceedingly complex. A convenient yardstick, as the authors point out, so necessary for setting the conditions for test, is the relevant B.S. specification. Here I have my tongue in my cheek when I say that it seems that, while before 1955 motors were designed so as not to comply with B.S.169, since 1955 they have been built so as not to comply with B.S.2613. That was my impression when I first read the paper.

I am not certain what the authors mean when they say that future policy towards rating standards should be 'flexible'. If it means that, in future, because of automatic control and other things, the motor should better fit the job, I am in agreement with them. Being too conservative in rating or having margins built in that are unrecognizable must surely put UK practice at a disadvantage compared with others, in cost, size, and performance.

Motor and supply rating also arise in the case of auxiliaries and, more acutely, in the case of those auxiliaries operating under highly sensitive and accurate position control. The peak accelerating torques may well dictate the size of the machine and of the supply while the reduction of motor inertia may, as the authors point out, necessitate the use of forced ventilation. As an aside here, may I ask whether forced ventilation from the commutator end is better than blowing air through from the other end? Is it not better to exhaust the air and any carbon dust at the commutator end?

For the power supply to the main drives the paper clearly shows advantages and disadvantages of mercury-arc converters. More information as to the nature, the amount, and frequency of the harmonic currents likely to be drawn from the supply might have been included. Furthermore, a comparison between supply capacities and the size of the largest mercury-arc rectifier reversing drives permissible on such supplies would be a useful guide for many applications.

When comparing mercury-arc and Ilgner sets, the authors are somewhat tentative in their figures of savings in energy cost when they say that these may be 'up to 10% or more'. How much is 'or more'? Would it not be better to say, 'up to 20%'?

On variable voltage drives fed from mercury-arc rectifier converters the power factor deteriorates as the voltage is lowered. The authors should have included this as one of the disadvantages of the system compared with the synchronous motor-driven MG set, a fair comparison in that neither can have a buffer energy store.

For the supply to auxiliaries and for the excitation system there is no doubt that static converter systems other than mercury-arc rectifiers will be used in the not-too-distant future. As the authors hint, we shall see static conversion equipment not of the mercury-arc type but possibly of the semi-conductor type.

The part of the paper dealing with automatic control raises certain questions of fundamental importance. As the authors say, to improve productivity, marginal losses in the efficiency of operation should be reduced, and this can be done by introducing automatic methods. It is doubtful, however, whether full consideration has been given in the industry as a whole to all the aspects of making automatic actions which were originally carried out by hand and, more recently, under hand control but motor driven.

One fundamental issue which arises is the question whether electric motors are the right actuators for some of the motions. An electric motor is not necessarily the best for driving a linear motion, and the screwdown drive is a case in point, although here the mechanical advantage of a screw mechanism is probably a good reason for persisting with this means of operation.

The positioning of the side-guards is a motion which more obviously could be approached with hydraulic methods in mind, not merely because of its linear motion but mainly because hydraulic methods might lend themselves better to being part of a position control servo system.

As the authors have shown, fast responses are necessary in order to obtain shortened overall times of the rolling programmes. But these fast response times cannot be obtained with high static friction, high inertia, and backlash within a closed-loop servo of the position control type.

Much attention has been given during the last 20 years to

the fundamental mathematical principles underlying closed-loop control and to electrical, hydraulic, and pneumatic methods of achieving very high accuracies and excellent dynamic characteristics. The state of the art is so well developed that as far as the closed loop of the controller is concerned, any static accuracy and transient response required in practice can be achieved.

The trouble arises when one combines the controller, an excellent closed-loop control system, with the driven mechanism, in servo terminology the 'plant'. In many instances, particularly in the position control field, the plant characteristics limit the overall performance, and the main trouble, as the authors point out, is stiction. This is vexing to those aware of the capabilities of the highly developed closed loops, and particularly vexatious to those of a mathematical turn of mind, because stiction completely upsets their beautiful calculations, which are comparatively straightforward when based on linear parameters.

So serious is the effect of stiction, as is evidenced from the paper, that attention should be paid to reducing it and making it comparable in value with the running or viscous friction, as has been done in other industrial applications, for instance in profiling machine tools. After all, what is a rolling mill other than a machine tool?

Good performance will not be attained until the design of the driven mechanism is reviewed. A rapid-acting position controller cannot in all cases be applied to a mechanism suitable for hand operation or even for motor operation under velocity control. The motors, actuators, their supplies, and driven parts, have among other factors to be designed to suit the high accelerating and decelerating torques.

The authors and others concerned with the design of control systems are to be complimented on the way in which they are pushing ahead with the improvement of their performance, but they are up against limitations outside their control. Close co-ordination of the design of the driven parts and the design of the controller is essential if the best use is to be made of the programme control devices so adequately dealt with by the authors in the latter part of an excellent paper.

Mr **Brown** (in reply): We accept the comments on references. While certain of the material in the second half of the paper has not previously been referred to there are, we agree, many references dealing with the fundamental problems involved and a short list is given at the end of this reply.

We also accept Mr Ovens' suggestion for using the word 'greatest' instead of 'maximum' when referring to rms torques. His reference to terminology brings out a point which was not stressed in the paper. The correct definition and understanding of terms has always been of great importance and this is particularly so with automatic control. In fact, the more complex systems become, the more important it is to have a clear understanding of what we are talking about. The specification of the performance requirements of automatic position control is an excellent example of this, and still all too frequently instances occur where very stringent specifications are issued stating extreme degrees of accuracy where in fact what is required is a consistency of performance to the degree stated, under known conditions.

Departures from British Standards for machines have arisen of course, because these standards were in the main written for general-purpose industrial motors and were not intended to cover completely the case of heavy industrial drives. The departures are, however, in the direction of giving more value for money and not less. There are, of course, other conditions specified in British Standards besides overloads and temperature rises. Perhaps the most satisfactory solution is for the manufacturer to make reference to the relevant British Standards and to state departures therefrom. In fact B.S.2613 does make specific provision for agreement between the user and the manufacturer for a modified rating specification to meet special duty cycles.

Mr Ovens is correct in his interpretation of the meaning we intended in our statement concerning flexibility in future policy towards rating standards. However, our main point is that any consideration should always go beyond the design of a particular unit in the system. To obtain the most effective system the design of the whole system and the compatibility of the units contained within the system must be considered.

Mr Ovens asks whether it is not better to exhaust the air and any carbon dust from the commutator end of an auxiliary motor. The advantage of blowing the air in at the commutator end is that it helps to keep the commutator cool. The construction of mill-type motors is such that pulling the air through the machine from the commutator is not detrimental. For this reason introducing the air at the commutator end has been universally adopted.

We did not enter into the detailed consideration of the effect of harmonics on the supply system because of the general nature of the paper. At present in the UK very careful consideration has to be made in each specific instance. References 5 and 6 at the end of this discussion review the fundamentals of the problems involved. The frequency and amplitude of the harmonics generated by a given type of rectifier connexion are fixed and in fact are stated in B.S.1698 (1950).

No fixed rules have yet been laid down for the percentage harmonic currents that can be permitted but recommendations have been put forward by the CEGB for the guidance of area boards. At present these recommendations cover only free-firing rectifiers, and to adapt these for use with grid-controlled rectifiers, the amount of harmonic increase due to grid control must be calculated and the resultant reduction factor applied.

For savings in energy cost, we have estimated figures of 11–12% and we have one isolated case where we estimated 15%. We are awaiting further experience to confirm our estimates. All indications are, however, that the saving should be up to 10% in the majority of cases.

We completely agree with Mr Ovens' concluding remark. The larger the scope of the system concerned the more important it is that we maintain a flexible mind in order that we choose the correct method of achieving any of the functions, even though this method may be a radical departure from previous practice. To obtain the most satisfactory system a close co-ordination of all the parts of the system is essential, as we have already mentioned. This will require the co-operation of the engineers concerned, on all aspects of equipment design and works production, far more so than has been necessary in the past, and to an increasing extent as systems become more complex.

Mr **P. Watkins** (AEI Heavy Plant Division): May I congratulate the authors on what I consider to be an excellent presentation of the trends in electrical equipment and some of the factors which influence those trends for plate mills.

I am pleased that the authors have drawn attention to the difference in the peak torque characteristics compared with the normal continuous torque according to UK, US, and Continental standards. Unless this is properly understood, considerable misunderstandings can arise when a British electrical manufacturer is asked to supply a main drive for a mill based on foreign design, or even supplied by a foreign mill maker.

In these cases, when specifying a maximum torque, the purchaser should state whether this is the cut-out or the maximum working peak and whether the drive has been rated in accordance with British, Continental, or NEMA standards.

It will be readily seen that for the same maximum working peak, the rms rating would be substantially different, depending on the standard used.

On large reversing mills, in order to calculate the actual rms of the duty cycle it is necessary to have complete knowledge of the rolling programme and also the inertia of the rotating masses. Up to recent years this usually meant that the electrical manufacturer was called upon to do a detailed calculation, but the tendency now seems to be for the purchaser or the mill maker to specify the rating based on experience in other mills.

It is therefore important that the principles on which the rating is based should be borne in mind particularly where

rolling practice indicates that the normal ratio of peak to rms torque may need further consideration.

While on the subject of the torque curves, I think there is a small error in the paper. It is stated that curve *C* in Fig.2 is the curve of cut-out torque whereas when reading the paper the authors said that it was maximum working peak, which is in fact true. It is also stated that curve *B* is the typical UK characteristic, but this is not strictly true if we interpret 'typical' to mean 'usual'. A machine can be designed with the working peak torque capability falling off above twice the base speed if the rolling conditions allow it, but a very careful investigation of the rolling programme would have to be made before I would consider it wise to put in a machine with a characteristic falling off in this way. Normally, if the machine were specified with 2½–1 speed range, it would be arranged that the inverse relationship between torque and speed was held right up to the maximum speed.

I think that all electrical manufacturers would endorse the use of static conversion equipment wherever possible for the reasons stated by the authors. However, progress in this field will be dependent on the suitability of the supply systems available, and the continued co-operation of the electricity authorities will be essential, particularly in regard to the questions of permissible voltage dip and harmonic interference.

The curves produced by the electricity authorities to date relating system capacity to converter load do not entirely cover reversing mill duty. However, several such equipments are being installed at the present time and it is to be hoped that some statement of future policy will be forthcoming when the effects of these equipments on the supply system have been analysed.

On the subject of static control equipment, each application should be considered strictly on its own merits and the question kept in the right perspective. Where reversible outputs are necessary and extremely high accuracies are not required there is no doubt that the rotating amplifier has a great deal to commend it. Where large power outputs and high degrees of forcing are required, the magnetic amplifier with reversing output is a far more expensive piece of equipment than the equivalent rotary amplifier, and there is nothing to be gained by interposing a pilot exciter between a low-power static amplifier and the large main exciter.

Static amplifiers come into their own only when the main equipment is static. The generator scheme using MA converters for excitation is a good example of this, and the completely static installation using MA converters to supply the main motor is even better.

There is no doubt that the days of the magnetic amplifier are numbered, as rapid advances are now being made in the field of semi-conductors.

On the choice of scheme, the first consideration is one of economics. As the Chairman said yesterday, if you had unlimited money you could have the perfect mill. There is no doubt that the cross-connected or 'figure eight' converter scheme is the most obvious and elegant method of obtaining a smooth transition from rectifying to inversion, but it involves doubling up on the rectifiers and makes the transformer more expensive. It would normally be considered at the moment only where absolute continuity of torque was essential to the operation of the mill. Economically there is very little to choose between the armature and field reversal schemes. The first involves a reversing switch and its control, and the second requires doubling up on the field converter to reverse the field.

I should like to dispel any fears about the reliability of the reversing switch. Switches are available in the UK which are very compact and entirely suitable for the duty imposed on them. Control systems are doubly interlocked to prevent operation while there is current flowing through the circuit.

The use of laminated motor frames is recommended to assist commutation during very high rates of current change, and these become practically essential for a field reversal scheme. Mercury-arc converters, as we all know, are subject to backfires under certain conditions, and even though precautions are taken to control temperatures etc., they are never entirely eliminated. On certain types of mill, continuity of supply is regarded as essential while a piece is in the mill. This possibly does not apply to plate mills as such, certainly not to single-stand mills unless extremely long lengths of plate are to be rolled. A figure was mentioned yesterday of 90 ft, in which case it might be considered desirable to have continuity of supply in the event of backfire. I should like to know the authors' views on this, particularly with respect to tandem rolling.

On the automation of mill controls, there is no doubt that techniques will advance as more and more attention is devoted to the subject. Of the storage systems mentioned in the paper, I would recommend either the tape or card systems as being the best at the present time from the point of view of simplicity and flexibility. Programme information can be quickly coded and typed out, and modifications to programme stores can be quickly carried out. Programme sorting on a reel of punched tape is extremely rapid using the system described in the paper and developed by AEI. I feel personally that the relay system is out-dated, involving, as it does, multi-contact selector relays. It is also rather inflexible and modifications to programmes are more difficult than with either cards or tape.

It is important to realize that automation of the mill itself is not the complete answer. Consideration must be given to the whole production line, from customers' orders to shipping. It is only in this way that the full benefit can be obtained from automation in the effort to increase overall productivity.

Mr **Brown** (in reply): I am glad that our thoughts coincide so much on the points Mr Watkins mentioned. For the correct application of a drive a thorough understanding of what that drive will do, together with a detailed knowledge of the duty cycle required and complete details of the mill equipment are essential and we thoroughly endorse what he has said on this aspect. As engineers attempt to get more and more out of mill plant this aspect becomes of increasing importance.

The torque characteristic curve which we showed was a typical curve and we agree that the point at which the working peak torque falls more rapidly than the inverse relationship between torque and speed, varies according to design and the particular top speed required. This aspect was shown, however, as it is a point which must be borne in mind because it can effect the design of large single armature high-speed motors on which a high ratio of top speed to base speed is required.

We agree about the rotating amplifier. In many cases it is a very good piece of equipment for the job to be done, and it often gives the most economic solution to the problem. Nevertheless, static converters are being used increasingly for excitation supplies and as amplifiers. In some cases a gain is obtained in running efficiency but the main reasons for their use are the fact that they are static and also because they lend themselves to building in with the control boards and hence reduce the amount of installation work to be done on site.

I heartily endorse Mr Watkins' remarks about reversing switches. Until recently there is no doubt that many users were worried about the reliability of such equipment but it must be remembered that the control circuit is arranged to prevent armature current flowing, by means of the rectifiers grid control, before operating the switch. Reliability of the reversing switch is therefore mainly a question of mechanical operation. This reliability can undoubtedly be provided in switches which still have very short operating times.

Many modern reversing mill motors already have laminated field frames and I agree this feature is becoming more desirable as we improve the control of the motor field.

For reversing mill drives we do not consider it is essential to ensure continuity of supply in case of a backfire. In the majority of cases the additional expense and complication is not justified. The essential feature is to ensure that control can be quickly regained after a backfire so that rolling can be continued, i.e. much the same as for an overload trip. In other types of drive where continuity of supply is essential we have used anode fuses with alarm indication, to clear the anode concerned, or auto-reclose high-speed breakers connected to a number of sub-groups of tanks, operating in parallel.

Turning to automation of mill controls, the uniselector relay system which was introduced by BISRA some years ago is a system which uses existing standard components and is very simple for the mill operator to use. Although it might be superseded by card readers and computers, the basic idea is sound and should not be forgotten because it often provides a simple answer to a fairly complex problem.

We fully endorse Mr Watkins' last remark. The mill is only one unit in the production line and while much can be gained by automatic control of each unit the full benefits of automation will only be obtained when it is applied to a complete, fully co-ordinated production line. The speed with which we achieve that ideal will depend on our sense of adventure, our willingness to explore and to learn, and our determination to get there.

Mr **T. Coxon** (Consett Iron Co. Ltd): 'Automation' is a word which, not without justification, makes managing directors, production managers, and mill managers shudder. In various parts of the world there are mills which are claimed to be automatic, but when one goes round these plants they are invariably in part, if not wholly, out of commission and working under manual control.

At Consett we have been rather cautious. We have preset control on the screw-down, not programmed; we preset for each pass. The main tables are individually driven. These are tied in and speed matched with the mill. For the ordinary operation of the through passes we have the sideguards tied with the mill, but when we come to turn the slab we use manual control.

It is interesting to note that with the mill in normal operation, main tables, breast rolls, and sideguards operating from the main drive control, the sideguards 'short stroke', i.e. the sideguards receiving the slab or plate open out a predetermined amount 10–20 in, while the sideguards on the entrance side of the mill remain positioned to guide the piece into the rolls.

At Consett we have gone ahead with the first twin reversing drive with mercury-arc rectifiers. There is one at Darlington of about 750 hp and questions were asked earlier at this meeting about information available on the capacity of the system which can take these loads. Our mill has a cutout at just over 30000 hp. The CEGB and NEB, in investigating the possibility of accepting this load, took into consideration the whole of any existing rectifiers and also all synchronous machinery.

Our present system is 500 mVA and our generating capacity is 45 mW. Most rectifiers we have are 12 phase. In the first stage of development with the 132-in mill the rectifiers will be 12 phase. The fault level at the end connexion is 2400 mVA and the level of our own system is lifted to 750 mVA.

With the mercury-arc drive it is interesting to note than in 1958 during a discussion* I said that it would be a very bold man who went in for the mercury-arc drive on a big mill and that the management would need some convincing! I trust that they will have no cause to regret their decision.

The authors did not state that there was considerable capital saving with mercury-arc rectifiers in place of the orthodox method and that possibly this saving is greater on a plate mill where the induction motor approaches the rms rating of the mill.

At Consett nine or ten years ago we carried out a scheme of development in a slabbing and roughing mill. Already it is obvious that the savings in capital in buildings and foundations with the new mill are significant. There is also a saving in the time in putting up the foundations. No doubt that will also apply to the installation.

Mr Ovens mentioned the effect of voltage drop. In the first stage the rectifiers are going in as 12 phase. If later we put in a roughing mill of capacity similar to the existing mill, that will be phased to give 24 phase. The whole job has been worked out and balanced to give the minimum effect of harmonics.

Mr Brown mentioned that the governing factor with mercury-arc rectifiers was connected with voltage drop and that this had more effect on television than on lighting. In that respect it is singular that with the Consett installation the only television equipment affected is that in our managing director's residence! He takes a supply from the system; no doubt we will have to arrange for a separate supply to his television.

Finally, I must raise one objection. A slide showing magnificent rectifier equipment which, incidentally, has been supplied to Consett, was described by the authors as 'hardware'!

Mr **N. D. Hyde** (Appleby-Frodingham Iron and Steel Company): Could the authors elaborate a little on the factors which affect the choice of mercury-arc as opposed to rotary conversion for auxiliary drive?

Mr **Brown** (in reply): For auxiliaries, mercury-arc converters still offer the advantages of more rapid control, easier maintenance, less noise and heat, and combined converter and control boards. However, the initial capital cost of the electrical equipment will usually be greater for the mercury-arc converter than for the MG set, particularly where back-to-back converters are required. The actual difference in cost of the two systems depends on the rating and duty cycle in each particular case. Energy costs will tend to be slightly less for the mercury-arc equipment but on a high-output mill the difference is not expected to be great.

The mercury-arc equipments for auxiliaries usually occupy more space than MG sets, particularly where back-to-back converters are required. Since auxiliary MG sets do not usually require heavy foundations mercury-arc converters do not usually offer any advantage in this respect.

I hope that what I have said answers the question in general terms. There will be a general trend towards static supplies for auxiliaries but at present each case should be given individual consideration before deciding upon the best system to adopt.

WRITTEN CONTRIBUTIONS

Mr **A. R. Parrish** (W. S. Atkins and Partners) wrote: It is well known that the electricity supply authorities in the UK have been very conservative in their approach to the imposition of large fluctuating loads on their systems. There appears to be a general belief that the criteria which the CEGB uses in deciding whether or not to allow a rectifier-fed mill or an arc-furnace to be connected to its system are still too severe, and I wonder if the authors would give their own views on the appropriate limitations. Mention was made in the discussion of the sensitivity to flicker voltages of television sets but, in any case, I think that American data based on incandescent lamp flicker, should be used with caution because of the greater thermal capacity of the thicker filament wire used in the American 115-V lamp, compared with the British 240-V lamp.

In response to the appeal in the discussion for a more extensive bibliography, some references on flicker may be of interest.[7]

The authors are undoubtedly correct when they say 'The only static conversion equipment at the moment that can meet the requirements of reversing mills is the mercury-arc converter . . .', but I wonder if they would be prepared to look beyond the present and give their views on the possible future application of grid-controlled semi-conductor rectifiers.

Authors' written reply

At present an investigation into these conditions is being carried out by the CEGB in conjunction with the ERA in order to determine definite limits of acceptability of voltage dips. This is, of course, an extremely difficult problem since the limits of acceptability are largely a matter of personal opinion. In the absence of information applicable to the UK the limits set have had of necessity to be somewhat arbitrary and to err on the conservative side.

The allowable limits vary with the particular circumstances. They can only be arrived at after consideration of several factors. These include the permissible amplitude and frequency of voltage dips generally acceptable for the supply system concerned, the 'stiffness' of a supply system and the presence of any particularly susceptible adjacent loads. Where the

* Discussion on the Ward-Leonard principle in steelworks: *JISI*, 1958, **189**, 344–350.

supply system is feeding a general area including domestic and other loads the voltage dip is usually limited to 1% or less. The problem can be eased by using an industrial bus system where the domestic load is completely isolated from the industrial load but these cases are rare in the UK. In the Ruhr, we believe, the majority of the industrial load is taken from a separate system which is only coupled to the domestic load at a point with a high fault capacity. For this reason we believe that higher voltage dips are permitted on Continental supply systems than would be the case in the UK.

Several Continental steelworks equipped with large converter-fed reversing mills are operating with voltage dips of the order of 5%. Where alternators are coupled to the works system this figure can be reduced appreciably if very high-speed excitation systems are used on these.

We would agree that great care must be exercised when applying the results of tests in the USA to problems existing in the UK.

Controlled semi-conductor rectifiers will undoubtedly play a very important part in future mill drive systems. They are already available for small drives. More operating experience is required with these relatively new devices before they will be universally applied, but this experience is being gained. While for the smaller auxiliary drives we feel it is safe to say that controlled semi-conductor rectifiers will be used fairly soon, we do not feel that the picture is sufficiently clear to say that they will find application on larger drives for several years. The main problem is, however, one of cost and if large, reasonably priced, reliable devices become available then we can expect them to be used for large drives.

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An appreciation of the late Eugene Gifford Grace, from the Bethlehem Steel Company

Eugene Gifford Grace, for many years a leader in the American steel industry and long the active head of Bethlehem Steel Company, died at his home in Bethlehem, Pa., on 25 July 1960, at the age of 83.

Mr Grace was born in Goshen, NJ, on 27 August 1876, the son of John W. and Rebecca (Morris) Grace. He attended the Goshen public schools, later was graduated from Pennington Seminary, Pennington, NJ. He then entered Lehigh University, where he was graduated in 1899 as class valedictorian, with a degree in electrical engineering.

Within a few days after commencement he entered the employ of Bethlehem Steel Company, in the Bethlehem Plant. The company at that time was only a small local enterprise specializing in ordnance, rails, and a few other miscellaneous products. His first job was crane operator. In 1902 he was advanced to superintendent of yards and transportation.

In 1904 Charles M. Schwab purchased the plant at Bethlehem and, combining it with other properties, formed Bethlehem Steel Corporation. He soon recognized the uncommon talent and energies of young Grace, and sent him to Cuba to reorganize the ore properties which the company then had there.

When Mr Grace returned from the successful completion of that challenging mission, he was made general superintendent of the Bethlehem Plant. His first major responsibility in that capacity was to supervise construction of the Grey mill, rolling the new wide-flange structural sections which changed the skyline of America by making possible the economical construction of skyscrapers.

Further advancements came rapidly to the young steelman. In 1908 Mr Schwab named him general manager of the company. In 1911 he rose to vice-president; in 1913 he was named president of the company; and in 1916 he became president of the corporation. In that capacity he served as directing head of Bethlehem during its peak war effort, when it was supplying large quantities of steel and ordnance materials to the United States and its allies.

There followed the reconverting of the company's war-oriented facilities to peaceful purposes, together with the long-range task of building up its capacity through expansion of facilities and acquisitions, together with the gradual shift of emphasis from heavy to light products.

Side by side with the company's material growth, progress was made on the human side. Mr Grace was always actively concerned with the human factors in industry. 'Any enterprise,' he once said, 'is no more and no less than a collection of human beings.' That belief was the motivating force behind his many pioneering moves in the interest of employee benefits and better employee relations. He early set up a department whose responsibility was the handling of industrial relations and other personnel matters.

During World War I, at a time when the promotion of safety was not taken for granted as it is today, he set up a safety programme in the company's steel plants and shipyards. Other advances on the human side which he pioneered were the Bethlehem relief plan, to protect employees and their families against the hardships resulting from sickness and death, and the Bethlehem non-contributory pension plan, which went into effect in 1923, 13 years ahead of Federal social security.

With the coming of the second World War, Mr Grace again made Bethlehem facilities available to the defence of the USA and its allies. During the six years of the conflict Bethlehem turned out over 73 000 000 tons of steel, and one-third of the armour and forgings for large-calibre guns for the US Navy, together with huge quantities of other war materials. The company's Ship-building Division carried out the largest and most diverse programme ever handled by a private organization, building 1 127 fighting and cargo ships, and repairing, converting, and servicing over 37 000 vessels.

A signal wartime accomplishment by Mr Grace was the development of the Controlled Materials Plan, which aided the Federal Government in solving the complex problems of ordering and allocating vital steels on an orderly basis through a central clearing organization.

Mr Grace continued, as chief executive officer, to direct the company's operations and its considerable expansion through the post-war years, until late in 1957 when failing health compelled him to relinquish his major responsibilities. However, he continued his association with the company in an advisory capacity, remaining honorary chairman and a director until his death.

Many honours came to Mr Grace in recognition of his accomplishments as a leader in the steel industry and builder of the enterprise he headed for so many years. These included the Gary Medal of the American Iron and Steel Institute; the Bessemer Gold Medal of The Iron and Steel Institute of Great Britain; the Rand Medal of the American Institute of Mining and Metallurgical Engineers; and the Gold Medal of The Pennsylvania Society. In 1957 he was made a 'Distinguished Life Member' of the American Society of Metals. His honorary degrees include Doctor of Engineering, Lehigh University; Doctor of Laws *Honoris Causa*, Trinity College, Hartford, Conn.; Doctor of Laws, Moravian College and Theological Seminary; and Doctor of Commercial Science, New York University. He served for many years as president of the Board of Trustees of Lehigh University, and later as honorary chairman of the Board.

Mr Grace's wife, Marion Brown Grace, died in 1956. He is survived by two sons, a daughter, eight grandchildren, and six great-grandchildren.

The Medal of The Iron and Steel Institute

The Medal of The Iron and Steel Institute was established in July, 1960 by the Council of the Institute, to be presented on special occasions to societies which, in the opinion of the Council, have rendered exceptional service to science or industry over a lengthy period.

The first Medal of The Iron and Steel Institute was offered to the Royal Society, in recognition of the Society's unique service to science over a period of 300 years. It was presented by the Hon. R. G. Lyttelton, Past-President of The Iron and Steel Institute, at the Tercentenary Celebrations of the Royal Society on 18 July 1960.

The second Medal was offered to the Verein deutscher Eisenhüttenleute to mark its first centenary, 1860–1960. It was presented by Mr W. F. Cartwright, D.L., J.P., President of The Iron and Steel Institute, at the 'Eisenhüttentag' celebrations in Düsseldorf during the first week in November.

The photograph shows the Medal of The Iron and Steel Institute, actual size. The Medal presented to the Royal Society was inscribed 'To Commemorate | The Royal Society | The Tercentenary 1960'. The Medal presented to the Verein was inscribed 'The Verein deutscher Eisenhüttenleute | 1860–1960'.

NEWS | *Announcements and News of Science and Industry*

THE IRON AND STEEL INSTITUTE

Annual General Meeting 1961

The Annual General Meeting of the Institute will be held in London on **Wednesday and Thursday, 3 and 4 May 1961.** There will be two parallel technical sessions, devoted to 'The use of computers in the iron and steel industry' and to 'Structural processes in creep' respectively. Full details will shortly be announced in the *Journal*.

The Dinner for Members will be held at Grosvenor House, Park Lane, London W1, on the evening of **Wednesday, 3 May.**

Election to Council

Mr H. W. A. Waring, C.M.G., deputy chairman and general managing director of GKN Steel Company Ltd, has been elected a Member of Council.

Iron and Steel Engineers Group

The next meeting of the Iron and Steel Engineers Group will be held at the Offices of the Institute on the afternoon of **Wednesday, 1 March,** and all day on **Thursday, 2 March 1961.**

There will be two papers for discussion, on mechanical and electrical features of the Lackenby beam mill of Dorman Long (Steel) Ltd, and the development of electric drives and control for high-speed cold-reduction mills respectively.

The full programme and registration forms will be circulated to Members shortly.

NEWS OF MEMBERS

Mr **W. F. Cartwright** (*President of The Iron and Steel Institute*) has been elected an honorary member of the South African Institute of Mining and Metallurgy.

Sir **John Duncanson** (*Honorary Vice-President*) has been awarded the gold medal *Scientia et Divulgatio* of the Rassegna Internazionale Elettronica Nucleare e Teleradiocinematografica, Rome, for outstanding work in the field of nuclear engineering.

Mr **A. N. Bicket** has resigned from the board of the Barrow Haematite Steel Company.

Mr **S. H. Brooks** has been appointed works manager (iron) at the Appleby-Frodingham Steel Company.

Mr **G. R. Buckley,** previously assistant managing director of the Stanton Ironworks Co. Ltd, has been appointed a deputy managing director of the company.

Mr **H. Stewart Craig** has retired as chairman of the directors of Llanelly Steel Co. (1907) Ltd.

Mr **Ambrose Firth** has retired as joint managing director of Brightside Engineering Holdings, Ltd. He remains a member of the board.

Mr **T. C. Firth** is now managing director of Brightside Engineering Holdings, Ltd.

Mr **K. M. Jones** has been appointed a director of Llanelly Steel Company (1907) Ltd, and has been elected chairman.

Mr **J. D. Joy,** director and deputy general branch manager of Appleby-Frodingham Steel Co., has become director and general manager.

Mr **J. T. Kowalczyk** is now manager of STAMFOR, Estampado y Forjado SA, San Francisco, prov. Cordoba, Argentina.

Dr **D. McLean,** of the National Physical Laboratory, has been promoted to the grade of Senior Principal Scientific Officer.

Dr **J. A. Naismith** has been appointed to the board of W. T. Flather Ltd.

Mr **G. Short** has left Arthur Lee and Sons Ltd to become assistant works manager, rolling mills, at the Spencer Works of Richard Thomas and Baldwins Ltd.

Mr **E. M. Summers** has been appointed a director of the Stanton Ironworks Co. Ltd.

Mr **J. B. Thickins** has been appointed chief metallurgist of the Spencer Works of Richard Thomas and Baldwins Ltd.

Mr **M. S. Vaughan** has been appointed a director of Llanelly Steel Company (1907) Ltd.

Mr **D. R. Wattleworth,** O.B.E., has been appointed a director of Barrow Ironworks Ltd.

Lt-Cdr **G. W. Wells,** D.L., managing director production, of The United Steel Companies Ltd has become chairman of the Appleby-Frodingham Steel Company.

Mr **C. H. Wilson** has been appointed a director of the Stanton Ironworks Co. Ltd.

Mr **M. G. Wright** is now a physical metallurgist with the atomic energy division of the General Electric Co. Ltd.

Obituary

Dr **Franz Leitner,** DR.MONT., DR.TECHN., DIPL.ENG. (*elected 1951*), of Wartberg im Mürztal, Austria, on 16 August 1960.

Mr **A. P. Taylor-Gill** (*elected 1946*), of Sheffield, on 20 November 1960.

AFFILIATED LOCAL SOCIETIES

Sheffield Metallurgical Association

The Association's Spring lecture programme 1961 is as follows:

10 Jan.*	Analysis group—Annual General Meeting
17 Jan.*	Refractories group—Annual General Meeting
24 Jan.	Association Annual General Meeting
31 Jan.	'*Tool Steels*', by G. Hoyle
7 Feb.*	'*Ion exchange—its development, significance, and use for ferrous analysis*', by Dr V. E. Gripp
14 Feb.	'*Some factors affecting impact properties*', by F. W. Bygate
21 Feb.†	'*Some aspects of basic refractories*', by J. Owen
28 Feb.	'*Martensite formation*', by Prof. W. S. Owen—joint meeting with The Institute of Metals, Sheffield section
7 Mar.*	'*The problems of ferro-alloy analysis*', by G. M. Holmes
14 Mar.	'*Creep relaxation*', by J. A. Stafford
20 Mar.	'*Technologists as successful managers*', by R. Coverdale
21 Mar.†	'*Recent developments in steelmaking techniques*', by E. Davies
28 Mar.	'*The role of ferro-alloys in modern steelmaking developments*', by Dr A. M. Sage

* Analysis group † Refractories group

All meetings will be held at BISRA Laboratories, Hoyle Street, Sheffield. Refractories group meetings will begin at 7.30 pm; all other meetings begin at 7 pm.

VEREIN DEUTSCHER EISENHUTTENLEUTE

'Eisenhüttentag' 1960

The Verein deutscher Eisenhüttenleute celebrated its centenary during the first week in November, when more than 5000 people, including 350 overseas visitors, met in Düsseldorf. The West German Federal Chancellor, Dr Konrad Adenauer, addressed the assembly on the final day of the meeting.

The Iron and Steel Institute was represented by the President, Members of Council, and the Secretary. Mr W. F. Cartwright (*President*) presented the Medal of The Iron and Steel Institute to the Verein. (*see opposite page*). It was received by the Chairman, Professor H. Schenk, DR.ING.

During the meeting the Carl-Lueg Medal, the highest award of the Verein was presented to Professor Robert Durrer, DR.ING. (*Member*), and to Dr Otto Lellep, in recognition of their contributions to the use of oxygen in steelmaking.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Automation Conference

The first conference on automation in the iron and steel industry was organized by BISRA and held at Buxton in October 1960. It was a closed conference at which Lord Halsbury gave the opening address, Mr S. S. Carlisle of BISRA gave a review of the present position regarding automation in the iron and steel industry, and was followed by Mr R. C. Gardner of The Reed Paper Group who delivered a paper on automation in the paper industry. The final session of the conference consisted of a 'brains trust' which produced much useful information.

The object of the conference was to stimulate interest in automation in the industry, spotlight the problems, and indicate possible solutions. BISRA hope that this conference will be followed by others which will consider more specific aspects of the subject.

Safety posters

'An experiment on the effect of specially designed safety posters' (BISRA Restricted report OR/HF/15/60) describes a research by S. Laner and R. G. Sell, carried out over 20 weeks with the help of seven steelworks. The authors found that posters can be effective for as long as three months if the posters are designed not as general exhortations to caution but with a specific situation in mind and employing positive instructions. Illustrations of the posters and a discussion of the experiment were published in the August 1960 issue of *Safety*.

THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Annual Exhibition

The annual exhibition of The Institute of Physics and The Physical Society will be held at the Royal Horticultural Society's Old and New Halls, Westminster, London SW1, on the following dates:

16 Jan. 10.30 am–7 pm (Members and press only 10.30 am–2 pm)
17 Jan. 10 am–9 pm
18–19 Jan. 10 am–7 pm
20 Jan. 10 am–1 pm

Demonstration-lectures will be given at 5.45 pm as follows:

17 Jan. *Hydrodynamic research* by F. S. Burt (Admiralty Research Laboratory)
18 Jan. *The physics of the oceans*, by Dr. G. E. R. Deacon (National Institute of Oceanography)
19 Jan. *Some physical problems in travelling at supersonic speed* by Dr F. P. Bowden (Laboratory for the Physics and Chemistry of Solids, University of Cambridge).

Tickets are available from The Institute of Physics and The Physical Society, 47 Belgrave Square, London SW1.

EDUCATION

Evening courses

The Division of Metal Science of the Borough Polytechnic, Borough Road, SE1, has arranged two special evening courses for the Spring term 1961:

Recent developments on non-electrolytic metal finishing: on Thursdays at 7 pm, beginning on 12 January 1961.
Metallurgy of rarer metals: on Tuesdays at 7 pm, beginning on 7 February 1961.

Both courses will consist of six lectures, given by specialists.

Apprentice training

Colvilles Ltd have opened a new apprentice training centre at Moss End, Lanarkshire. The centre cost almost £250 000 and has facilities for training 150 boys; there are departments for teaching engineering, foundry work, pattern-making, technical drawing, and training in the control of overhead cranes.

Course on failure in engineering

A special course of six lectures on the causes and prevention of failures is to be held at the Institute of Technology, Bradford, on successive Wednesday evenings at 7.0 pm, beginning on 18 January 1961. Application forms and further information may be had from the Registrar, Institute of Technology, Bradford, Yorkshire.

CONTRIBUTORS TO THE JOURNAL

T. J. Pitt, DIP.TECH., I.I.M., A.C.T.(BIRM.)—Research Assistant, Birmingham College of Advanced Technology.
Terence John Pitt was born in 1937 and educated at Queen Mary's School, Walsall, before joining the GKN Group Research Laboratories in 1953. After part-time study at the Wolverhampton and Staffordshire College of Technology he embarked in 1955 on a Diploma in Technology course at the Birmingham College of Advanced Technology. During this time his industrial training was arranged at the GKN Laboratories.

He has now returned to the Metallurgy Department of the Birmingham C.A.T. investigating the dry corrosion of a range of nickel alloys, to gain Membership of the College of Technologists.

R. H. T. Dixon, A.I.M.—The Mond Nickel Company Ltd, Development and Research Department, Birmingham.
R. H. T. Dixon was born in 1926 and educated at Handsworth Grammar School. After spending a year with Tube Investments Ltd he was awarded a bursary by the Birmingham Brassfounders which enabled him to study metallurgy at the Birmingham College of Technology, and to obtain an A.I.M. He then joined Mond Nickel, in whose Birmingham laboratories he has studied electro-plating, high-temperature alloys, steel castings, and

T. J. Pitt

R. H. T. Dixon

powder metallurgical processes, and where he is now the leader of the cast iron research section.

N. E. Moore, B.SC.—Physical Metallurgist, Metallurgical Section, Research Department, AEI (Manchester) Ltd.
Nigel Edward Moore was born in 1935 and educated at the Quakers' Yard Grammar School and University College, Swansea, where he obtained his B.SC.(HONS) degree in metallurgy and was awarded the Sidney

J. A. Griffiths

N. E. Moore

Gilchrist Thomas Medal in 1957. In that year, he joined the Research Department of AEI, where he has since been working on ferritic and austenitic steels for high-temperature applications.

J. A. Griffiths—Electron Microscopist, Scientific Apparatus Engineering Department, Instrumentation Division, AEI (Manchester) Ltd.
John A. Griffiths was born in 1929. After serving 2½ years in the RAF, he joined the Nuffield Rheumatism Research Unit in Manchester, and worked on photomicrography, microradiography, and medical illustration; he was for some years a member of the Institute of British Photographers, The Royal Photographic Society, and The British Federation of Master Printers. In 1954, he joined the Outside Erection Department of Metropolitan-Vickers Ltd, working on high-voltage particle acceleration equipment, and in 1958 he took a post in the Electron Microscope Applications Laboratory, where he is at present doing work on the application of the electron microscope to metallurgical problems.

NEWS OF SCIENCE AND INDUSTRY

Company news

Mr J. F. Parker (chairman), Mr G. St J. Strutt, C.B.E., and Mr E. S. Parker have retired from the board of *British Rolling Mills Ltd*. Mr J. F. Parker was a founder director of the company, Mr Strutt served as a director for 40 years, and Mr E. S. Parker has been connected with the company for nearly 50 years. Mr R. Ll. Lloyd has been appointed chairman.

Mr G. W. Ashton (general works manager) and Mr J. Elliot (secretary and chief accountant) have been appointed directors of *Firth-Vickers Stainless Steels Ltd*.

Barrow Ironworks Ltd have announced that *Leopold Lazarus Ltd* of London and Birmingham are now representing them through the Birmingham area and the south of England for the sale of hematite and semi-phosphorus pig irons.

Keeping reactors clean

A 'clean conditions shop' in which certain critical parts of atomic reactors are assembled, has been set up at the Tolleross works of Stewarts and Lloyds, Ltd, Pipework Engineering Division, Glasgow.

The clean shop has a floor area of 7000 ft² and is divided into two main compartments, one for vacuum-cleaning and dipping the parts in protective coating, the other for final assembly. It is of dust-proof construction with double-glazed windows and rubber-edged doors. The floors have a special surfacing and the rest of the interior is finished with a special gloss paint which is free from any constituents that might contaminate the products. Electrically heated and very highly filtered air is supplied under pressure. Personnel enter through a changing room and wear special white overalls, caps, gloves, and rubber boots.

The major assembly job at present being carried out in the shop is an order of more than 400 nuclear reactor control rod standpipes for the Hunterston nuclear power station. In certain circumstances the facilities of the shop may be made available to outside firms.

BCIRA Thirty-ninth annual report

BCIRA's annual report for the year ending 30 June 1960, includes summaries of the researches and advisory services carried out by its research and development departments and other sections; lists of member firms, and of lectures and papers delivered or published under its auspices; and its research programme for 1960–61, which besides studies in the association's central field includes studies of corrosion, atmospheric pollution, foundry atmospheres, and various analytical researches.

The report is available from the offices of the British Cast Iron Research Association, Alvechurch, Birmingham.

Inco president in London

Mr J. Roy Gordon, president of The International Nickel Company of Canada Ltd, held a press conference on his recent visit to London, the first he has made since he succeeded Dr J. F. Thompson as president early last year.

Mr Gordon gave a short illustrated talk on the company's extensive project at Thompson, Manitoba, where a new nickel mining and processing plant, said to be the second largest in the world, has been established in just over five years in extremely difficult conditions.

Lorry Mounted Crane Association

The inaugural committee of the Lorry Mounted Crane Association formed at the end of 1959 have now established rules of membership. The Association has set out to guarantee a minimum standard of insurance, safety, and reliability in lorry-mounted cranes, and hopes to rationalize legislation relating to their use.

The headquarters of the Association are at 301 Glossop Road, Sheffield 10, and further information is available from A. A. Greenfield, Stanch House, Bailey Lane, Sheffield 1.

British Standard miniature smoke chart

When the British Standard Ringelmann chart is used to assess smoke density, it needs to be located at a distance from the observer, and in a particular position in relation to the smoke discharge being examined. Such a limitation makes its use inconvenient in certain circumstances and as a result BS2742, a miniature smoke chart, has been developed for this purpose.

The grey shades painted on the chart have been found to give results in good agreement with those obtained by the Ringelmann chart. The miniature smoke chart is not, at this stage, offered as a complete substitute, but it it hoped that experience with it will confirm the preliminary findings and enable it to achieve equal status with the Ringelmann chart proper. An amendment (PD 3901) to BS2742 'Notes on the use of the Ringelmann chart' has been issued to explain the method of use, and a summary of it is printed on the envelope containing the miniature smoke chart.

Copies of this standard may be obtained

from the British Standards Institution, Sales Branch, 2 Park Street, London W1, price 3s single copies; 12 for 24s, and 144 for £10. Postage will be charged extra to non-subscribers.

NIFES in 1959–60

The sixth progress survey and report of the National Industrial Fuel Efficiency Service surveys a year of increased activity. An analysis of the industrial groups using the service shows 134 specifically in the iron and steel industry, and a further 722 in engineering and metals.

Surveys have been made on boiler plant and steam distribution and most types of furnace, even lime kilns. In an earlier survey on rolling mill furnaces methods were described whereby fuel savings of 22% had been made. More recent work has been on steel forging and stamping shops and reheating furnaces, and results have lead to reduced fuel consumption as well as increased output, better furnace loading, and improved product quality.

The report, which is finely printed and richly coloured, is available from area offices of NIFES or the head office at 71 Grosvenor Street, London W1.

Contract News

Quasi-Arc Ltd have received an order from Sulzer Brothers of Winterthur, Switzerland, for a complete automatic welding installation for the fabrication of penstock pipes (as used in hydroelectric schemes).

Wild-Barfield Electric Furnaces, Ltd, are at present fulfilling several contracts, including nearly 50 furnaces for India, a crystal pulling furnace for Belgium, and a high-temperature furnace for the Royal New Zealand Air Force.

Thomas Smith and Sons (Rodley) Ltd have received an order from the Admiralty for eight diesel shunting engines of 5–10 tons capacity, and two 10-ton diesel-electric shunting cranes. Delivery is for this year.

George Wimpey and Co. in association with the *United Engineering and Foundry Company* of Pittsburgh, have been awarded a £440 000 contract for the installation of rolling mills at the new Spencer steelworks of Richard Thomas and Baldwins.

Brown, Lenox and Co. Ltd have received orders for £400 000 worth of mill conveyors and equipment from companies including Richard Thomas and Baldwins, Colvilles, and the Steel Co. of Wales Ltd.

The General Electric Co. Ltd have received two contracts totalling £362 000 from Richard Thomas and Baldwins Ltd. for the Spencer Works; and an order valued at £139 000 for supplying and installing a turbo-blower at the Cleveland Works of Dorman Long (Steel) Co. Ltd.

CORRIGENDA

In the paper 'Investigations of failures in a blooming mill' by *F. E. Stacey* (*JISI*, 1960, **196**, Oct., 195–207) the author has indicated two errors which occurred in the original manuscript.

p.195, line 37, for *10 500 ingot tons per year* read *10·500 ingot tons per week*.

p.200, Table I 'Typical monthly rolling cycle'. In col.1, *week 3* should read *week 4*, and the analysis for week 3 is as follows:

Description	*Finish dimensions*
Sheet, Bar	12 in wide, 0·25–0·9 in thick
Slabs	10 in × 2 in up to 16 in × 2½ in
Billets	2½ in × 2½ in
Tonnage	*Cogging dimensions*
2 500	12½ in wide × 2–2½ in thick
5 400	+ 10½ in wide × 4½ in thick
3 100	5½ in × 5½ in
11 000	

The paper 'The physics of oxygen steelmaking' by *C. Holden and A. Hogg* (*JISI*, 1960, **196**, Nov., 318–332) was wrongly ascribed to the Iron and Steel Engineers Group. Also, on p.327, Fig.7 related to the work of Holden and Hogg only, and the right-hand graph in Fig.8 on the same page should have been credited to Fage and Johansson.

CHANGES OF ADDRESS AND TITLE

Samuel Osborn and Co. Ltd, Sheffield, have opened a new warehouse at 7 Millfields Road, Bilston, to stock tool steels, engineers' small tools, and files for customers in Birmingham and Midlands.

The Hydronyl Syndicate Ltd will in future be known as *Hydronyl Ltd*.

FORTHCOMING CONFERENCES AND EXHIBITIONS

Engineering, marine, welding, and nuclear energy

The next Engineering, Marine, Welding, and Nuclear Energy Exhibition will be held at Olympia, London, from 20 April to 4 May 1961.

Ninth Colloquium Spectroscopicum Internationale

The Ninth Colloquium Spectroscopicum Internationale will be organized by the 'Groupement pour l'Avancement des Méthodes Spéctrographiques' (GAMS) and will take place at Lyons in the Palais des Congrés Internationaux from 5 to 10 June 1961.

The topics covered will include: atomic spectroanalysis, nuclear and radical spectroanalysis, and molecular analysis. The lectures will be of three kinds: authoritative lectures on their work by eminent scientists; reports from specialists on the most recent advances in various fields of spectrographic chemical analysis: technical and scientific papers on original work.

There will be a large exhibition of instruments in the International Congress Building. A whole day will be set aside for works visits around Lyons. On the last day members will be offered a choice of excursions. A special programme will be provided for ladies for the duration of the conference.

GAMS are also arranging two journées internationales devoted to the study of methods of direct separation and chromatography on 13 and 14 June in Paris.

Further details of both the colloquium and the international days may be had from: Groupement Pour l'Avancement des Méthodes Spectrographiques, L.N.E., 1 rue Gaston Doissier, Paris XVe.

DIARY

4 Jan. SOCIETY OF CHEMICAL INDUSTRY, CORROSION GROUP—Cathodic Protection Panel meeting: discussion on galvanic anodes by G. E. Gardam, P. V. Palmer, and K. P. Scott—14 Belgrave Square, London SW1, 6 pm.

11 Jan. NORTHAMPTON COLLEGE OF ADVANCED TECHNOLOGY—'*Modern metallographic techniques*'; first of a course of 12 meetings, Wednesday afternoons—St John Street, London EC1, 2 pm.

12 Jan. INSTITUTE OF METALS—Lecture, '*Metallurgical research at high pressures*', by Dr J. E. Hilliard—17 Belgrave Square, London SW1, 6.30 pm.

16 Jan. SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Short symposium '*Welding versus casting*', R. Weck and A. H. Sully—The Engineering Lecture Theatre, St George's Square, Sheffield, 7 pm.

16–20 Jan. INSTITUTE OF PHYSICS AND PHYSICAL SOCIETY EXHIBITION—Royal Horticultural Society Old and New Hall, London, SW1.

17–19 Jan. INSTRUMENT AUTOMATION EXHIBITION AND CONFERENCE—St Louis, USA.

18 Jan. SOCIETY OF CHEMICAL INDUSTRY, CORROSION GROUP—Lecture, '*Metallic diffusion coatings*', by R. L. Samuel—14 Belgrave Square, London SW1, 6 pm.

18 Jan. ROYAL INSTITUTE OF CHEMISTRY—Lecture by Prof. Sir Cyril Hinshelwood—King's College, Strand, London WC2, 6.30 pm.

18 Jan. INSTITUTION OF MECHANICAL ENGINEERS—Symposium, '*Pressure vessel research towards better design*'—1 Birdcage Walk, London SW1.

19 Jan. THE INSTITUTE OF METALS, SHEFFIELD LOCAL SECTION—Lecture, '*Ductile fracture*', by Prof. R. W. K. Honeycombe—Applied Science Building, The University, St George's Square, Sheffield, 7.30 pm.

19 Jan. INSTITUTION OF MINING AND METALLURGY—Meeting—Geological Society, Burlington House, Piccadilly, London W1, 5 pm.

20 Jan. WEST OF SCOTLAND IRON AND STEEL INSTITUTE—Lecture, '*Relative merits of different steelmaking processes*', by T. F. Pearson—39 Elmbank Crescent, Glasgow, 6.45 pm.

24 Jan. INSTITUTION OF ELECTRICAL ENGINEERS—Discussion, '*Machine-tool control*', opened by Dr E. H. Frost-Smith—Savoy Place, London WC2, 5.30 pm.

25 Jan. INSTITUTE OF BRITISH FOUNDRYMEN, LONDON BRANCH—Lecture, '*Developments in the production of gunmetal castings*', by F. Hudson—Constitutional Club, Northumberland Avenue, London WC2, 7.30 pm.

25 Jan. ROYAL INSTITUTE OF CHEMISTRY—Lecture, '*Magnetism in inorganic chemistry*', by Prof. R. S. Nyholm—College of Further Education, William Street, Slough, 7.30 pm.

25 Jan. INSTITUTE OF WELDING, NORTH LONDON BRANCH—Lecture, '*Practical aspects of CO_2 welding*', by F. Collins—54 Princes Gate, London SW7, 7.30 pm.

25 Jan. MANCHESTER METALLURGICAL SOCIETY—Lecture, '*Residual stress and stress relieving*', by Dr D. A. Melford—Literary and Philosophical Society, George Street, Manchester, 6.30 pm.

26 Jan. SOCIETY OF CHEMICAL INDUSTRY, CORROSION GROUP—Conversazione, 14 Belgrave Square, London SW1, 6.30 pm.

27 Jan. NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS—Lecture, '*Fatigue strength of marine shafting*', by G. P. Smedley—Mining Institute, Newcastle-upon-tyne, 6.15 pm.

30 Jan.–2 Feb. NATIONAL PLANT MAINTENANCE AND ENGINEERING SHOW—Chicago, USA.

31 Jan. SOCIETY OF INSTRUMENT TECHNOLOGY—Lecture, '*Three terminal bridge measurements and automation*', by M. A. Butterfield and J. Dowsing—Manson House, Portland Place, London W1, 7 pm.

1 Feb. SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Lecture, '*The steam/oxygen converter process at Abbey Works*', by M. C. Harrison—Central Library, Swansea, 6.45 pm.

1 Feb. SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Joint meeting with the Institute of Mechanical Engineers, '*Avoidance of failures*', by G. A. Cottell—The Engineering Lecture Theatre, St George's Square, Sheffield, 7 pm.

1 Feb. THE NEWCOMEN SOCIETY—Lecture, '*The draining of the Alport mines, Derbyshire*', by Miss N. Kirkham—Science Museum, London SW7, 5.30 pm.

1 Feb. THE SOCIETY FOR ANALYTICAL CHEMISTRY—Meeting on '*X-ray fluorescence*'—Burlington House, London W1, 6 pm.

1 Feb. INSTITUTE OF PETROLEUM—Meeting—61 New Cavendish Street, London W1, 5.30 pm.

1–4 Feb. AMERICAN PHYSICAL SOCIETY—Meeting—New York.

2 Feb. THE ROYAL INSTITUTION OF NAVAL ARCHITECTS—Lecture, '*Sea trials on two cross-channel, twin-screw ships*', by Prof. Ir. G. Aertssen—10 Upper Belgrave Street, London SW1, 4.45 pm.

2 Feb. INSTITUTE OF METALS, LONDON LOCAL SECTION—Lecture, '*The development of some new bearing materials*', by P. G. Forrester—17 Belgrave Square, London SW1, 6.30 pm.

3 Feb. STAFFORDSHIRE IRON AND STEEL INSTITUTE—Annual Dinner—Wulfrun Hall, Wolverhampton, 7.15 pm.

3 Feb. ROYAL INSTITUTE OF CHEMISTRY—Lecture, '*Research and development in DSIR stations*', by Sir H. W. Melville—Brighton Technical College, 7.30 pm.

6 Feb. CLEVELAND INSTITUTION OF ENGINEERS—Lecture, '*Blast furnace operations at Clay Lane ironworks*', by A. T. Ledgard and P. K. Gledhill—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 6.30 pm.

6 Feb. ROYAL INSTITUTE OF CHEMISTRY—Lecture, '*Fuel cells*', by H. H. Chambers—Society of Chemical Industry, 14 Belgrave Square, London SW1, 6.30 pm.

6 Feb. SOCIETY OF INSTRUMENT TECHNOLOGY, DATA PROCESSING SECTION—Lecture, '*The universal decision element*', Professor J. E. Parton and A. Rose—Manson House, 26 Portland Place, London W1, 6.30 pm.

6–17 Feb. CITY OF LIVERPOOL COLLEGE OF TECHNOLOGY—Course, 'Radiation safety and health physics'—The College, Liverpool.

7 Feb. SOCIETY OF CHEMICAL INDUSTRY, CORROSION GROUP—Short papers evening—Engineering Centre, Stephenson Place, Birmingham, 7 pm.

7 Feb. ROYAL INSTITUTE OF CHEMISTRY Lecture, '*Organic reactions in strong alkalis*', by Prof. B. C. L. Weedon—Sir John Cass College, Jewry Street, London EC3, 6.30 pm.

7 Feb. THE INSTITUTE OF WELDING, SLOUGH SECTION—Lecture, '*Pipeline welding*', by R. J. Wright—Community Centre, Farnham Rd. Slough, 7.30 pm.

7 Feb. LEEDS METALLURGICAL SOCIETY—Lecture, '*Metals in antiquity*', by R. F. Tylecote—Metropole Hotel, Leeds, 6.30 pm.

8 Feb. THE INSTITUTE OF WELDING AND S. L. BRANCH JOINT TECHNICAL MEETING—Lecture, '*The welded Maidenhead bridge*', by Gilbert Roberts—54 Princes Gate, London SW7, 6.30 pm.

8 Feb. INSTITUTION OF MECHANICAL ENGINEERS INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP—Lectures, '*The influence of measuring force, stylus radius, and surface finish on the accuracy of measurement of work pieces by a comparator*' by L. W. Nichols and T. R. J. Oakley; and '*An investigation into the accuracy of industrial measurement of sizes between 0·02 and 5 in*', by P. W. Harrison—1 Birdcage Walk, London SW1, 6 pm.

8 Feb. MANCHESTER METALLURGICAL SOCIETY—Lecture, '*Residual stress and stress relieving*', by L. E. Benson—Manchester Literary and Philosophical Society, George St., Manchester, 6.30 pm.

9 Feb. LIVERPOOL METALLURGICAL SOCIETY—Lecture, '*The origin and solution of some industrial corrosion problems*', by E. C. Campbell—Department of Metallurgy, The University, Liverpool, 7 pm.

9 Feb. EAST MIDLANDS METALLURGICAL SOCIETY—Lecture, '*The modern production and metallurgy of blackheart malleable cast iron*', by H. Greatorex—Derby and District College of Art, Derby, 7.30 pm.

10 Feb. NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS—Lecture, '*Heavy-lift vessel* "Adventurer" ', by C. Stephenson—Mining Institute, Bolbec Hall, Newcastle-upon-Tyne, 6.15 pm.

13 Feb. LINCOLNSHIRE IRON AND STEEL INSTITUTE—Films—North Lindsey Technical College, Kingsway, Scunthorpe, 7.30 pm.

13 Feb. ROYAL INSTITUTE OF CHEMISTRY—Lecture, '*Reaction mechanisms*', by Prof. E. D. Hughes—North-West Kent College of Technology, Miskin Road, Dartford, 7.30 pm.

14 Feb. SOCIETY OF CHEMICAL INDUSTRY, CORROSION GROUP—Lecture, '*The occurrence of fire-side corrosion in modern steam generators*', by W. D. Jarvis and D. B. Leason—14 Belgrave Square, London SW1, 6 pm.

14 Feb. ROYAL INSTITUTE OF CHEMISTRY—Lecture, '*The work of a public analyst*', by T. McLachlan—Norwood Technical College, Knight's Hill, West Norwood, London SE27, 7 pm.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on page 466 of the December 1960 issue of the *Journal:*

Irreversible potentials and corrosion resistance of metals. SHATALOV, A. YA., *Inst. Fizich. Khimii, Akad. Nauk SSSR, Trudy*, 1955, (5), pp.237–266. (£9 10*s*. 0*d*.) [**1442**

Basic arches and roofs of metallurgical (including copper-refining) furnaces. HÜTTER, L., *Radex Rund.*, 1959, Oct., pp.629–639. (£4 15*s*. 0*d*.) [**1601**

Large electric steelmaking furnaces. HAMMARLUND, P. E., *Tek. Tidsk.*, 1959, Aug. 14, pp.721–728. (£4 10*s*. 0*d*.) [**1683**

On the measurement of the interstitial carbon and nitrogen contents, and the strain-amplitude dependence of internal friction in commercial steels. AOKI, K. *et al.*, *Nippon Kinzoku Gakkai-si*, 1959, Dec., pp.696–698. (£5 10*s*. 0*d*.) [**1755**

Internal friction in quench-hardened low-carbon steel and cold-worked iron. ICHIYAMA, T. *et al.*, *Nippon Kinzoku Gakkai-si*, 1959, Dec., pp.717–721. (£9) [**1756**

Technical and economic comparison of gas and induction heating for forgings. SCHAEFER, H., and RUCH, H., *Praktische Energiekunde*, 1959, (2), pp.107–141. (£7 15*s*. 0*d*.) [**1758**

Measurement of wear in drawing steel bar by means of radioactive drawing tools. LUEG, W., and FUNKE, P., *Stahl u. Eisen*, 1959, July 9, pp.996–1002. (£4 10*s*. 0*d*.) [**1772**

The water economy of an integrated iron and steelworks. KNECHT, E., *Stahl u. Eisen*, 1960, May 26, pp.751–756. (£4 5*s*. 0*d*.) [**1785**

The behaviour of large electric drive motors during the reversal of the direction of rotation. NÜRNBERG, W., *Stahl u. Eisen*, 1960, April 14, pp.514–520. (£4 10*s*. 0*d*.) [**1798**

Experience with squirrel-cage induction motors of special design for steelworks cranes (with discussion). WORTBERG, H., *Stahl u. Eisen*, 1960, April 14, pp.520–535. (£3 15*s*. 0*d*.) [**1799**

Comparative economics of open-hearth and arc furnaces for production of unalloyed low-carbon steel. KREBS, E., and PAKULLA, E., *Stahl u. Eisen*, 1955, Jan. 13, pp.9–24. (£10) [**1805**

Results of an investigation into hot-blast stoves. KESSELS, K., *Stahl u. Eisen*, 1955, July 28, pp.958–974. (£9) [**1808**

Determination of pore size distribution in refractory materials. PAMPUCH, R., *Prace Inst. Hutn.*, 1959, (1), pp.11–17. (£5 10*s*. 0*d*.) [**1818**

Contribution to the determination of low boron contents in steels. LEEB, A. J., and HECHT, F., *Radex Rund.*, 1960, (1), pp.62–66. (£2 10*s*. 0*d*.) [**1828**

Developments in wire rope fatigue testing. ROSSETTI, U., *Transporti Industriali*, 1959, July–Aug., pp.1126–1128. (£1 15*s*. 0*d*.) [**1832**

Filming the internal movement of metal in the deformation zone during the metal rolling process. MUZALEVSKII, O. G., *Zhur. nauch. i. priklad. fotog. i kinemat.*, 1958, (5), pp.363–367. (£3 10*s*. 0*d*.) [**1839**

The development and production of pre-stressed steel St.150 in the German Democratic Republic. STRUVE, G. VON, *Neue Hütte*, 1960, Feb., pp.78–89. (£6 5*s*. 0*d*.) [**1840**

Effect of drawing temperature when drawing steel wire.—II. NISHIOKA, T., *Nippon Kinzoku Gakkai-si*, 1958, May, pp.225–229; 229–233. (£7) [**1848**

Mills constructed by TsKBMM with new rolling techniques: combination mill for cold rolling of thin strip; planetary mills for tube rolling; mills for rolling sheet and T-sections of variable cross-section. TSELIKOV, A. I. *Sovremennye Problemy Metallurgii* (Contemporary problems of metallurgy), Moscow, Akad. Nauk, 1958, pp.475–480; 480–481; 493–499. (£7) [**1849**

Use of the large 80-ton arc furnaces at the Breuil steelworks of the Société des Forges et Aciéries du Creusot (with discussion). COLIN, J., *Rev. Mét.*, 1960, June, pp.481–490. (£4) [**1850**

The influence of vacuum casting on certain properties of steels (sheet). (with discussion) COLOMBIER, L., and ROYER, C., *Rev. Mét.*, 1960, June, pp.491–499. (£4 15*s*. 0*d*.) [**1851**

The effect of initial structure on the creep behaviour of a 2·25%Cr–1%Mo steel at 550°C. GEIGER, Th., Int. Disc. on 'Long-time behaviour of high-temperature steels', Düsseldorf, 24–25 June, 1960. (£4) [**1855**

Wind tunnel tests on the wind resistance of a twin tubular bridge girder. BARTH, R., *Der Stahlbau*, 1960, **29**, June, pp.186–191. (£3 15*s*.) [**1881**

The notch sensitivity of a Cr–Mo–V steel for bolt work operating at elevated temperatures. WACHÉ, X., Int. Disc. on 'Long time behaviour of high temp. steels', Düsseldorf, 24–25 June 1960, Paper No.23. (£3 15*s*. 0*d*.) [**1887**

The determination of the rolling forces during cold rolling. WENZEL, M., *Stahl u. Eisen*, 1959, Dec. 10, pp.1872–1875. (£2 10*s*.) [**1891**

Permissible heating and cooling rates of thick-walled pipelines. GRASS, G., and WÜRKER, K. G., *Allgemeine Wärmetechnik*, 1956, (10), pp.211–219. (£3 15*s*. 0*d*.) [**1898**

The application of infra-red spectroscopy to the determination of mineral constituents in slags and refractory systems. PEPPERHOFF, W., *Arch. Eisenhütt.*, 1958, March, pp.153–158. (£3 5*s*. 0*d*.) [**1902**

Stainless steels for oil pipelines. Comparison of European with USA steels. SCHAEBEN, L., *Erdöl u. Kohle*, 1958, Sept., pp.636–639. (£2 10*s*. 0*d*.) [**1903**

The effect of heat treatment on the development of carbides in chromium-molybdenum steels. BÄCKER, L. *et al.*, *Mem. Sci. Rev. Mét.*, 1960, July, pp.527–534. (£4 10*s*. 0*d*.) [**1918**

Continuous casting. (*a*) Iron and steel. (with a world list of installations). WITTMOSER, A., *Giesserei*, 1959, Oct. 22, pp.718–722. (£2 5*s*. 0*d*.) [**1920**

Theory of the course of pressure in extended industrial furnaces. HANSEN, M., *Arch. Eisenhütt.*, 1960, June, pp.337–342. (£4 5*s*. 0*d*.) [**1932**

The use of explosives in repair work on ferro-alloy furnaces. PETRMAN, I., *et al. Hutnik*, (Prague), 1959, (8), pp.273–276. (£4 15*s*. 0*d*.) [**1935**

Comparison between pickling of steel in phosphoric acid solutions, and pickling in sulphuric acid and hydrochloric acid solutions. DUNK, G. VON DER, *Stahl u. Eisen*, 1960, Sept. 29, pp.1318–1321. (£2 10*s*. 0*d*.) [**1947**

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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* Abstracts, the reference to which is marked with an asterisk, are or are to be made available as translations.

ABBREVIATIONS AND LIST OF PERIODICALS EXAMINED BY THE ABSTRACTING SERVICE

AB Metal Digest (Illinois)
AEG Progress (Berlin)
AEI Engineering Review (London)
Abhandlungen der Braunschweigischen wissenschaftlichen Gesellschaft (Brunswick)
Abstracts Journal Metallurgy (New York, London)
Academia Republicii Populare Romine, Studii si Cercetari de Mecanica Aplicata Studii si Cercetari de Metalurgie (Bucharest)
Académie Polonaise des Sciences (Warsaw)
Bulletin Chimique
Bulletin Mathématique
Bulletin Technique
Acciaio Inossidabile (Milan)
Acero y Energia (Barcelona)
Acier-Stahl-Steel (Brussels)
Aciers Fins et Spéciaux Français (Paris)
Acta Chimica Sinica (Peking)
Acta Crystallographica (London)
Acta Metallurgica (Toronto)
Acta Metallurgica Sinica (Peking)
Acta Mineralogica-Petrographica (Szeged)
Acta Physica Polonica (Warsaw)
Acta Physica Sinica (Peking)
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Products Finishing (Cincinnati)
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Teknisk Ukeblad (Oslo)
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ABSTRACTS

These abstracts are also available on index cards in advance of publication in the *Journal*, each abstract being classified under the Universal Decimal system (UDC). Details and subscription notes can be obtained from the Secretary, The Iron and Steel Institute.

MINERAL RESOURCES

Iron ore from Mauritania M. Crowder (*Min. J.*, 1960, **255**, Sept. 9, 282–284, from *Steel News*) An account of the Khédia deposits and plans for exploitation.

Iron ore from Maurstania M. Crowder (*Steel Rev.*, 1960, July, 39–43) With colour photographs.

Review of mineral fuels and the principal metals and minerals in France in 1959 (*Ann. Mines*, 1960, July–Aug., 374–408) Iron ores are reviewed, pp.379–381, also Ni (396–398), Mn (398–400), and W (402–403). **Review of the mineral industries in 1959 in overseas territories of the French Zone apart from N. Africa, the North Sahara, The Antilles, Guiana, and Réunion** (409–433). **Statistics** (434–534).

ORES—MINING AND TREATMENT

Formation of fayalite in roast reduced jaspilite J. B. Lean, K. J. Tucker, B. O. Holland, and T. R. Thomson (*Nature*, 1960, **187**, Aug. 20, 683–684) A letter. Reduction much above 650°C gives lower rates, lower recoveries and less break-up of the ore. This is shown to be due to formation of fayalite instead of magnetite. The fayalite bonds magnetite to quartz and hinders reduction.

Design for a standard apparatus for determining the reducibility of iron-ore sinters V. I.

Korotich and V. K. Gruzinov (*Stal'*, 1960, (8), 694–695) Apparatus of thermogravimetric type with a vertical quartz tube and a gas preheater is figured and described.

Dedusting and classifying minerals in the fine-size range with corona-type separators I. N. Plaskin and N. F. Olofinsky (*Bull. Inst. Min. Met.*, 1960, **69**, Aug., 613–626) The development of corona-type dedusters, their efficiency with 0–7 mm materials, and their power for gravity separation are described.

Shelton iron and steel's ore preparation and sinter plant (*Brit. Steel*, 1960, **26**, Feb., 59–63) An account of the construction and operation of the ore preparation, ore handling and sintering plant which began production early in 1959. It has an initial capacity of 5000 t/week and a final capacity of 8350 t/week, from one machine. A second sintering machine can easily be installed.

Self-agglomerating fluidized-bed reduction B. G. Langston and F. M. Stephens jun. (*J. Met.*, 1960, **12**, April, 312–316) The finely-divided concentrates from the beneficiation of the low-grade Michigan and Minnesota deposits are suitable for direct reduction in a fluidized-bed unit. Principles of the process, and the results of experimental work are reviewed.

Ore concentration of fine-grain iron spar by means of fluidized-bed sintering W. Heilmund (*Z. Erzberg. Metallh.*, 1960, **13**, July, 301–312) Siegerland iron spar requires a beneficiation treatment, usually sintering in the shaft furnace with subsequent magnetic separation. The effect of oxygen on sintering in the shaft furnace was studied, it was found that with decreasing oxygen available, magnetization increases, but magnetization still depends on the proportion of the fines in the burden. In fluidized-bed sintering a process seems to have been found which allows sintering of fines. In laboratory trials sludge additions up to 40% did not impair the sintering process, but with higher sludge additions sintering is incomplete and magnetic separation becomes impossible. Fluidized-bed sintering, on a laboratory scale, is described and results are reported.

Operating a disc pelletizer S. V. Bazilevich (*Stal'*, 1960, (8), 683–685) The operation of the pelletiser is analyzed and the dimensions and rates regulating its performance are identified and optimum conditions are calculated. Advantages over drum pelletizers are noted.

Production of fluxed pellets from fine concentrates D. G. Khokhlov (*Stal'*, 1960, (8), 686–690) Trials with disc and drum pelletizers are reported on the conditions and especially on the particle size distribution, necessary to produce good pellets for blast-furnace use from fine magnetite and roasted pyrite concentrates. Various methods of firing were studied and the importance of temp. control within narrow limits was confirmed. The pellets formed had much more mechanical strength than sinter and were well suited to blast-furnace use.

Fuel economy in grid sintering M. Auxenfans (*Centre Doc. Sidér.*, 1960, **17**, (5), 1171–1182) Solid fuel is the largest cost item involved in grid sintering (almost 50%). This article describes numerous methods which have been developed to try to reduce consumption of solid fuel—charging in two beds (Knutange type), prolonged firing, hot-air sintering, gas combustion 'in situ', charging in two beds (Jennings type), and pre-drying. It is concluded that optimum firing conditions must be ensured. The use of secondary burners can lead to substantial fuel saving although this is accompanied in certain cases by a reduction in output. Careful preparation of the mixture to be sintered resulting in regular operation will also bring about economics.

Study of self-fluxing sinter A. Ishimitsu, T. Furui, and S. Wakayama (*Tetsu to Hagane*, 1960, **46**, Feb., 123–129) Tests on a range of mixtures of limestone and Larap ore are reported. Limestone addition increased permeability, decreased sintering time, increased the microstrength of sinter, and gradually decreased the reducibility as a result of increase of slag. It should be possible to determine conditions for increasing the desulphurization ratio.—K.E.J.

A study of the conditions for the intensification of the sintering process and the production of high basicity fluxed sinter N. V. Kois and A. I. Komissarov (*Stal'*, 1960, (8), 698) A brief note from Chelyabinsk. Sinter pot trials showed that sinter with a $CaO:SiO_2$ ratio of 1:4 could be produced which would eliminate limestone from the charge. This was shown in trials to raise productivity and decrease coke consumption, also to improve sulphur removal.

Vertical cylindrical sintering machine N. Z. Plotkin, G. G. Oreshkin, and A. K. Rudkov (*Stal'*, 1960, (8), 696–697) A plan and an illustration of a model are shown. The charge is fed into an annular space and removed from the bottom by a plough. It is claimed to be much more compact than a conventional machine of the same output.

Production of sponge iron in rotary kilns and experience of its use in blast furnaces A. I. Gimmel'farb and G. I. Chasovitin (*Stal'*, 1960, (8), 691–694) The process is more suitable for Orsk–Khalilovo ores than magnetic roasting as regards Ni recovery and transfer of Cr to the slag. The operation of the blast-furnace is not changed, but the coefficient is improved and coke rate and lime consumption are reduced. Other ores should show similar properties.

FUEL—PREPARATION, PROPERTIES AND USES

Factors affecting the cleaning of fine coals by the Convertol process Shiou-chan Sun, W. L. McMorris (*Min. Eng.*, 1959, **11**, Nov., 1151–1156) Laboratory trials with this oil phase-inversion process in a Waring Blendor are reported, and the slimes suitable for treatment and the oils used can be selected by this test.

Investigation on the thermogravimetric testing of coal J. A. Corrales Zarauza (*Inst. Nac. Carbon Bol. Inf.*, 1959, **8**, Sept.–Dec., 150–156) The apparatus and procedure used for the thermogravimetric analysis of coal are described and examples of the curves obtained are reproduced.

Durgapur coke ovens lit up ahead of time (*Iron Steel Rev.*, 1959, **3**, Aug., 33–35) These Simon–Carves coke ovens are part of a new integrated iron and steel works. The part they will play in the development of the works is described, and the experience gained by Simon Carves in coking plant manufacture in India is briefly reviewed. The difficulties that have had to be overcome by the British consortium that is building this works are mentioned.

Heating of coke oven batteries M. A. Rico (*Inst. Nac. Carbon Bol. Inf.*, 1959, **8**, Sept.–Dec., 163–196) The heating-up of a coke-oven battery is examined in great detail. The properties of the structural materials used are reviewed and the maximum daily rise of temp. is calculated and related to the required gas consumption to obtain this result, allowance being made for drying, radiation, and other losses. Temp./time diagrams for making the preliminary calculations are derived, and results tabulated (22 refs).

Explorations in coke making research with a full scale coke oven model A. H. Brisse and J. G. Price (*AISI Reg. Tech. Meetings*, 1959, 105–123) A report on the effect of coal sizing on patterns of variations based on a series of tests carried out in a wooden test oven in order to investigate relationship of coal charge sizing to coal distribution in the commercial coke oven.

Comparison of the measurements of the reactivity of coke W. Peters (*Glückauf.*, 1960, **96**, July 30, 997–1006) Coke samples from coking trials were given to four institutes for examination of the reactivity. The four institutes measured the reactivity by different methods, but in spite of the great deviations in the testing methods the results showed very good agreement. It is, however, suggested that one of the testing methods should be standardized to obtain a closer co-operation between the various research and testing stations. The results showed that the reactivity of the coke depends mainly on the final coking temp., whereas the course of the coking process does not seem to have any influence.—T.G.

Assessment of the influence of coking rate on the mechanical properties of the coke J. R. García-Conde and E. Alvarez Miyar (*Inst. Nac. Carbon. Bol. Inf.*, 1959, **8**, Sept.–Dec. 157–162) The trials described were carried out on cokes from different blends coked simultaneously in ovens of different widths but with almost identical flue temp. For the blends examined 450 mm ovens were found, on the basis of Micum tests, to be more suitable than 350 mm ovens.

Ammonia—product of and servant to steel H. J. Weiland (*AISI Reg. Techn. Meetings*, 1959, 367–383) The plant and process of Ketona Chemical Corp. at Ketona, Ala, are described by the works manager, followed by a general discussion.

AIR POLLUTION AND SMOKE

Atmospheric pollution S. H. Brooks (*Appleby Frodingham News*, 1960, **13**, Spring, 5–11) A review with notes on control measures for blast-furnace plant.

The phytotoxic effect of dust emissions and measures for their prevention E. Pelz (*Technik*, 1960, **15**, Aug., 549–555) The phytotoxic effect of dusts from various industries such as metal smelting is reviewed, and suggestions put forward for legislation in the German Democratic Republic for checking air pollution.

TEMPERATURE MEASUREMENT AND CONTROL

Pyrometers—Measurement, recording and control. Part V (*Trattamenti Term.*, 1959, **2**, Sept.–Oct., 22–25) This article describes the method of regulating temp. based on the principle 'all or nothing'. This causes hunting and constant temp. cannot be maintained. More recently the principle of phase displacement has been applied with great effect to this problem. A compensating device combined with the usual regulating mechanism is used which consists of a differential thermocouple inserted in the circuit of the thermocouple of the regulator. The operator by this method can take compensating action in heating or cooling.

Metallic thermocouples for the measurement of temperatures above 1600°C [Engelhard Industries Ltd] (*Metallurgia*, 1960, **61**, March, 141–142) The advantages and disadvantages of the various couples available for temp. measurement above 1600°C are discussed. The various couples produced by Engelhard Industries Ltd are listed and details are given.

REFRACTORY MATERIALS

Refractories: A review of the literature published in 1958 K. Konipicky and G. Routschka (*Stahl Eisen*, 1960, **80**, Aug. 18, 1163–1167) (76 refs).—T.G.

Refractory materials for the iron and steel industry. Part II J. M. Palacios Reparaz (*Dyna*, 1960, **35**, Feb., 102–114) [In Spanish] A comprehensive review of the properties, manufacture, and applications of alumina-silica bricks is supplied together with data on the raw materials used. Mention is also made of special bricks of the sillimanite and alumina types.

Basic refractories for the steel industry M. A. Fay (*Iron Steel Eng.*, 1960, **37**, May, 89–105) Development of basic refractories and their design, construction, and applications are reviewed, with a summary of the future outlook.

The increase in specific gravity of silica bricks when heated to high temperatures K. Konopicky and I. Patzak (*Trans. Brit. Ceram. Soc.*, 1960, **59**, June, 213–223) Reheating for a long time at 1500°C increases sp. gr. This is attributed to the properties of pseudo-wollastonite and its behaviour in presence of tridymite and cristobalite.

A new plant for gunite lining of industrial furnaces A. N. Novikov, O. P. Berezinskii, A. G. Ganeev, and S. M. Lebedev (*Stal'*, 1960, (8), 712–713) A system of mechanized hot repair using a pumping system and hopper mounted on wheels for spraying powdered refractory-clay paste is described.

Siliceous clay for refractory linings Decrop (*Centre Doc. Sidér.*, 1960, **17**, (4), 987–1000) After defining natural siliceous clays and stating briefly how they differ from foundry sands, an analysis is made of their clay content and the size distribution of silica grains in order to assess their quality.

Mineralogical and refractory properties of Almora magnesite M. Ramakrishna Rao, P. C. Sen, and H. V. Bhaskar Rao (*Refract. J.*,

1959, **35,** Sept., 270–271) A review. Analyses and the effects of additions of rutile, ilmenite, bauxite, and schist are shown.—S.H.-S.

Investigation and testing of 32 high-grade mortars for fireclay brick G. R. Eusner and J. R. Bachman (*Refract. J.*, 1959, **35,** Sept., 268–269) A report on petrographic and chemical analytical tests of 32 brands of high-grade fireclay mortars, with tabulated cup-joint slag-test results.—S.H.-S.

Studies in refractoriness of firebricks under load J. C. Banerjee and D. N. Nandi (*Refract. J.*, 1959, **35,** Oct., 297–298) A report on Indian experience with moderate and high heat duty firebricks.—S.H.-S.

Production of test specimens in refractory materials G. Castledine (*Refract. J.*, 1959, **35,** Oct., 292–294) Trepanning and other machine operations used for testing refractory bricks for tensile, tension, creep, and other properties are described and safety methods are indicated.

Iron spots in silicon bricks: Part III. Interim reports on field trials L. Sabiston (*Refract. J.*, 1959, **35,** Dec., 347–349) An interim report on field trials, with the general conclusion that no differences in performance have been reported between material with and without iron spots.

Contribution to the study of dolomitic mixtures. Growth of a dolomite works as a function of research on the compactness of mixtures Decamps and Bonnier (*Centre Doc. Sidér., Circ.* 1959, **16,** (10), 2193–2203) On the basis of tests to determine the mixture of dolomite sizes giving the maximum density, the existing dolomite plant has been modified for the production of the required amount of fines. The average convertor lining life has been increased from 360–482 casts.—A.G.

Firing tests on dolomite and attempts to measure the degree of bonding J. Baron (*Centre Doc. Sidér.*, 1959, **16,** (8), 1763–1770) Absolute and apparent densities and porosities of five raw dolomites, fired and bonded at increasing temp. are reported. A method of assessing the degree of bonding is suggested.

Thermal shock resistance in ceramic materials L. Ferrer Olmos (*Rev. Ciencia. Apl.*, 1960, **14,** May–June, 238–244) Investigations of the properties of ceramic materials are reviewed with respect to the assessment of thermal shock resistance. The important factors such as tensile strength, modulus of elasticity, Poisson's ratio, and, most important, coefficient of expansion and thermal conductivity are considered. The materials are grouped and discussed according to their dilatation coefficients and a series of feldspathic porcelain mixes, fired to 1 350°C, has shown the importance of the dilatation coefficient as a measure of thermal shock resistance (45 refs).

IRON AND STEEL—GENERAL

Steelmaking in the Soviet Union F. M. Rich (*AISI Yearbook*, 1959, 45–72) An account of a visit to the USSR. Capacity, output, methods, training, and research are discussed.

The miracle of Chinese steel A. Cresta (*Tecn. Indust.*, 1960, **38,** June, 883–887) The author describes the rapid increase in Chinese steel production by small-scale, local methods. This development is used as a text by the author to discuss the planning of the Argentine industry. The Chinese example, together with the tendency to build medium-sized plant in Europe, suggest that small-scale plant which could be more widely dispersed is a most economical approach to national development.

1959 Perspective of production and technique of iron and steel in Japan T. Yamaoka (*Tetsu to Hagane*, 1960, **46,** Jan., 3–6).—K.E.J.

The Japanese and Asiatic steel industries G. Grenier (*Mines Met.*, 1960, July–Aug., 421–423) This article is mainly devoted to describing the plant, production, and development programmes of the main Japanese steel companies. Tables show investment expenditure on various types of steelmaking plant since 1956 and information is given showing how expenditure on the plant for the production of the various types of products has progressed during the same period. The raw materials are discussed, emphasizing Japan's dependence on foreign supplies. The article concludes with brief notes on steelplant and production in China, Burma, Formosa, Indonesia, Southern Korea, Pakistan, Philippines, Thailand, Malaya, and Hong Kong.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Some aspects of modern blast furnace practice W. D. Millar (*AISI Rev. Techn. Meetings*, 1959, 385–413) The three blast-furnaces of US Steel Corp. at Fairless Hills, Penn., are described and their method of operation discussed, with reference to current Russian practice.

New blast-furnace charging gear N. S. Shchirenko, V. P. Dobrov, A. M. Khmara, and Ya. G. Skripka (*Stal'*, 1960, (8), 698) An arrangement is shown, with a brief description, in which three superimposed hoppers are used to give better distribution and to minimize greatly the number of times the upper bell has to be lowered. The device is intended for operation at high top pressures to reduce the abrasive effect of entrained dust.

Remarks on the charging by skip and rotating MacKee top of blast furnace No.6 at Senelle G. Masse (*Centre Doc. Sidér. Circ.*, 1959, **16,** (11), 2373–2380) The charging system is described and its performance is assessed from the aspects of radial and peripheral segregation, reproducibility and flexibility. The main shortcoming is poor peripheral distribution and possible ways of overcoming this are indicated.—A.G.

Experience with self-fluxing sinter at the Steel Co. of Canada Ltd J. S. McMahan (*AISI Yearbook*, 1959, 75–122, discussion 123–138) A discussion of sinter and blast-furnace practice with results of a trial on four furnaces. Full analytical figures are shown and the value of sinter is stressed.

A new correlation of blast penetration in a blast furnace G. C. Gardner (*Trans. Met. Soc. AIME*, 1960, **218,** June, 423–430) A new correlation of blast penetration in model and operating blast-furnaces is presented which overcomes objections to previous correlations. The tuyere dia. appears only of small importance in determining the magnitude of the penetration. The data from operating furnaces correlate satisfactorily with the data from models where the cross-section is a segment of a circle.

Carbon bricks for lining blast furnaces D. W. Hubbard (*Research*, 1959, **12,** Aug.–Sept., 322–325) The use of carbon linings is briefly described and discussed.—S.H.-S.

Charge hanging with oxygen-enriched blast M. A. Stefanovich (*Stal'*, 1960, (8), 680–683) The resistance to gas flow increases with the use of O_2 (and with rise of blast temp.) because of more rapid descent of the charge, less complete reduction during slag formation and more rapid combustion of coke. These factors may also cause hanging of the charge.

A new hot-cooling system for metallurgical furnaces F. Bukau (*Neue Hütte*, 1960, **5,** June, 337–348) The underlying principles and main features of various hot-cooling systems are reviewed, and a new system is described, which has been developed in the Forschungsinstitut für technologische Entwicklung und Wärmetechnik der Metallurgie, Leipzig, which is simple in design and economical to operate (22 refs).

Slag formation in the blast furnace smelting of fluxed sinter B. N. Starshinov, V. P. Onoprienko, V. L. Pokryshkin, P. H. Netrebko, and D. S. Yalovoi (*Stal'*, 1960, (8), 673–680) Sampling arrangements were made on a 1 248 m^3 furnace producing foundry iron. The position of slag formation was found to be largely at the furnace wall and the dissociation region of limestone and the CO_2 and CO distributions were similarly mapped. Sulphur is absorbed by the lime mainly at the hearth. The effect of raising basicity from 0·7 to 1·0 was investigated. The conclusions are questioned in an editorial note.

Emptying and cleaning a blast furnace stack G. Masse (*Centre Doc. Sidér. Circ.*, 1959, **16,** (8), 1741–1751) A description is given of the blowing out of a furnace using atomizing water sprays to regulate top temp., followed by dynamiting of a scaffold.—A.G.

Stock descent in a blast furnace before dynamiting P. Jourde (*Centre Doc. Sidér. Circ.*, 1959, **16,** (8), 1753–1762) Blowing out of a 5·5 m dia. furnace was accomplished with the aid of atomized water sprays which kept top temp. down to a satisfactory level.—A.G.

Use of agglomerates during the shut down of a blast furnace for rebuilding or repairing the stack at Aciéres et Miniéres de la Sambre C. Caudron (*Centre Doc. Sidér. Circ.*, 1959, **16,** (10), 2171–2181) Experiences with the charging of +10 mm sinter during the shutdown of three furnaces are reported. The sinter is able to absorb sufficient water to keep down the top gas temp. and flows easily after the furnace is blown out.—A.G.

Analysis of blast furnace performance. Method of adjusted coke rates G. Thibaut (*Centre Doc. Sidér. Circ.*, 1959, **16,** (7), 1541–1553) After correction of the coke rate for variations in blast temp., Si and carbon in the iron, slag weight and basicity, etc., there are still residual errors between furnaces. It is shown that these deviations largely disappear if hearth dia. is taken into account, there being a marked reduction in heat consumption as the furnace size increases.—A.G.

Measurement of the wear of blast furnace brick work with a radioactive isotope. I A. Tominaga, T. Yatsuzuka, and S. Shono (*Tetsu to Hagane*, 1960, **46,** Jan., 7–11) Voice's method using a ^{60}Co tracer was investigated. Preliminary work included measuring absorption coefficients of B.F. constructional materials, determining the amounts of tracer to be enclosed, and tests with a brick model. **II** (Feb., 130–134) Twenty-two ^{60}Co specimens were buried in the brickwork of Kamaishi No.1 furnace when it was relined. The state of wear has been measured weekly for over a year; within four weeks, two specimens at one-third of the depth of the bosh brickwork were lost.

Recent improvements in cleaning blast furnace stoves H. Rudich (*Iron Steel Eng.*, 1960, **37,** May, 151–152) The use is described of power-driven, flexible solid-spring steel rod developed by National Power Redding Corp. for cleaning blast-furnace stoves.

Trials on Gerin Cowpers at U.C.P.M.I. D. Sanna and G. Warynski (*Centre Doc. Sidér. Circ.*, 1959, **17,** (11), 2381–2397) These Cowper stoves with the Gerin system of chequers had a high gross thermal efficiency (92%) and a low resistance to flow. The importance of selecting the correct size of orifice in this type of stove is stressed.—A.G.

A study of the reduction of chrome ores S. S. Lisnyak (*Stal'*, 1960, (8), 698) A brief note from Chelyabinsk. Measurements on reduction by solid C and controlled Co pressure were made.

Report of the pig-making division (*Tetsu to Hagane*, 1960, **46,** July, 797–798).

Reports of the 54th Committee (Pig making) Japanese Society for the Promotion of Science (*Tetsu to Hagane*, 1960, **46,** July, 799–803).

Kalinga Industries Ltd's low shaft iron furnace in Orissa Kalinga Industries (*Iron Steel Rev.*, 1959, **3,** Aug., 37–38) The building of a furnace to reduce iron ore rejects (of size $\frac{1}{8}$–1$\frac{1}{2}$ in) is described. The furnace was designed by Krupp of Essen, and is being run on nut coke of $\frac{1}{8}$–1$\frac{1}{2}$ in size for the present. Due to the lack of metallurgical coke reserves in India, this sort of furnace seems to have a promising future. Such furnaces could also be economically built to provide pig iron for foundry use.

'California iron ore' H. E. Henderson (*Foundry*, 1959, **87,** Nov., 218–224) An account is given of an early trial of the 'Driscoll' process for making iron. This involved charging a column of lignite, iron ore, and limestone into an electric furnace hearth. Doubtful economics stopped the application to Californian iron ores.—A.G.

Direct reduction of iron ore R. R. Rogers (*Department of Mines and Technical Surveys, Ottawa, Mines Branch Information Circular IC* 109, 1958, Oct., pp.13) Several typical direct reduction processes are described briefly, namely the H-iron, Madaras, Wiberg-Söderfors, Stelling, R–N, Kalling, Strategic-Udy, and Krupp-Renn processes.

Fundamental thermodynamics of the reduction of iron oxides L. C. Correa da Silva (*Bol. ABM*, 1960, **16,** July, 617–640) The thermodynamical considerations necessary to understand the reactions in the blast-furnace and

other reduction processes are described. It is pointed out that these fundamentals can be derived only by a careful study of the C–Fe–O ternary system. This ternary diagram is considered and correspondence is shown between points of the binary, C–O, and the pseudo-binary, C–Fe–O; this correspondence clearly shows the significance of the oxidation-reduction diagram of the Fe–C–O system. It is pointed out that some errors may be found in published versions of this diagram; these are described and corrected. A comparison with the oxidation-reduction diagram of the Fe–H–O system is made.—P.S.

Kinetics of hydrogen reduction of magnetite J. M. Quets, M. E. Wadsworth, and J. R. Lewis (*Trans Met. Soc. AIME*, 1960, **218**, June, 545–549) Samples of synthetic magnetite were reduced in H_2 at various partial pressures and temp. The reaction was found to be surface controlled and directly proportional to hydrogen partial pressure over the temp. range studied (400° to 1000°C). A transition in the mechanism occurred at approximately 590°C. This has been attributed to a change in the slow step of the reduction reaction resulting from the presence of stable wüstite at higher temp. Below 590°C the heat of activation for the reduction was found to be 14 700 cal/mole and it was 3200 cal/mole above 590°C.

Results of treating iron with sodium sulphide to remove copper A. Simkovich and R. W. Lindsay (*Trans. Met. Soc. AIME*, 1960, **218**, June, 565–570) The possibility of using Na_2S slags to remove copper from ferrous alloys has been investigated by Jordan and Langenberg. In these studies such slags were found to be capable of removing copper and sulphur from the melt. This article describes further investigations made to clarify the effects of temp. on copper removal.

Report on masks for protection against blast-furnace gas M. Malvaux (*Centre Doc. Sidér.*, 1960, **17**, (5), 1183–1199) This article gives the results of a questionnaire sent to works regarding protective masks and describes the masks used, together with their performance.

An economic assessment of the applications of the Krupp-Renn process to the siliceous Lorraine ores J. Astier and G. Turpin (*Centre Doc. Sidér.*, 1960, **16**, (4), 919–930) The price per t of pellets has been calculated for ores of varying quality and technical and economic data are given for each cost item. In relation to the usage value of the Krupp-Renn balls (about 180 new francs/t) siliceous ore of 30–33%Fe content can be used.

Nu-iron, a fluidized-bed reduction process T. F. Reed, J. C. Agarwal, and E. H. Shipley (*J. Met.*, 1960, **12**, April, 317–320) The principle of the process developed by US Steel Corp. is outlined, and pilot-scale trials are described, from which it is shown that the process is technically feasible. A reducing gas is preheated, and the ore is reduced in two stages.

H-iron production by Alan Wood R. A. Lubker and R. W. Bruland (*J. Met.*, 1960, **12**, April, 321–324) A description of the design and operation of the first commercial H-iron installation, the Alan Wood plant, for the production of iron powder. Bethlehem Steel are constructing a second unit in Southern California.

Specifications for lubricants and lubricated parts in iron smelters H. Böer (*Stahl Eisen*, 1960, **80**, Aug. 18, 1169) A review of the German DIN specifications in this field.—T.G.

PROPERTIES, TREATMENT AND USE OF SLAGS

Production of slag wool in the foundry shop A. S. Serovi (*Lit. Proizv.*, 1960, (1), 38–39) At the Sukreml' Foundry, cupola slags are used to make mineral (slag) wool in the cupola in which iron is melted, without a second melting of the slag. The melting is done with coke, the consumption of which amounts to 16–17% of the slag. The molten slag is atomized by steam under a pressure of 6–7 atm and a special arrangement for the purpose is described.

Study of slag viscosity and the selection of ideal slag composition for single-stage melting of silicochromium N. L. Zhilo (*Stal'*, 1960, (8), 715) A note from Chelyabinsk. Slags with 45%SiO_2 are the most fluid over a wide range of $MgO:Al_2O_3$ ratios.

PRODUCTION OF STEEL

For the first time—over 200 000 tons of steel per month (*Werk. u Wir*, 1960, **8**, May–June, 159–161) To mark the attainment of a record crude steel production of 200 000 tons by Westfalenhütte in March 1960, this article reviews the development of steelmaking plant and production there over the past 80 years.

The development of the modern steelmaking processes with special regard to the metallurgical phenomena involved M. Hater (*Mitt. Forschungs. Blechverarb*, 1960, (15–16), Aug. 10, 188–194) A lecture delivered at a meeting of the society, reviewing the present-day trend in steelmaking.—T.G.

Oxygen in iron melting A. M. Samarin (*Bergakademie*, 1960, **12**, May–June, 262–270) The activity of O_2 in liquid iron, deoxidation reactions with Si, solubility of O_2 in Fe–V melts, changes in O_2 solubility in Fe–Si alloys under high vacuum, and the influence of various elements on the solubility of O_2 in iron melts are among the subjects considered with reference to the literature (30 refs).

More tonnage oxygen for steelworks (*Metallurgia*, 1960, **61**, March, 104) New tonnage oxygen plants are to be built in the vicinity of various steelworks. The capacities of the proposed plants are given.

Unattended oxygen plants G. P. Andersen (*Chem. Eng. Progr.*, 1960, **56**, May, 58–60) The important features that ensure safe operation of a plant which functions automatically and entirely without operating labour, being kept locked and checked daily or weekly according to size, with the addition of a safety monitoring system to a supervisor, are described; and design, instrumentation, construction, and maintenance practices are presented and discussed.—S.H.-S.

Oxygen processes for iron and steel making II K. Morinaga (*Tetsu to Hagane*, 1960, **46**, July, 775–787) A review (95 refs).

New method of investigating the equilibrium in the system metal-slag V. F. Sourov, O. V. Travine, and L. A. Schwarzman (*Principes Physico-Chimiques de l'Elaboration de l'Acier*, pp.291–295) Partition of constituents is measured by passing radioisotopes through the slag into the metal; the method is an improvement on the technique proposed by Zhukhovitsky and Zhuravlev in that larger amounts of metal can be used, giving better control.

Kinetics of decarburisation in molten steel. IV. Effect of temperature, area in contact with crucible wall, area of free surface and rotation on the rate of decarburisation T. Fujii (*Tetsu to Hagane*, 1960, **46**, Jan., 12–19) Results from a high-frequency induction furnace are given. Allowing for decarbonization by the crucible wall (MgO), the rate of decarbonization is linear with temp. to 1500–1650°C. It is linear with the area of free surface of molten steel. With rotation, it is linear with the area of the free surface of the paraboloid of rotation.

Basic oxygen steel making J. E. Tredinnick (*AISI Reg. Techn. Meetings*, 1959, 215–232) A report on the effect of basic oxygen production between Dec. 1958 and June 1959, in the Fontana, Cal., plant of the Kaiser Steel Corp. with tabulated data.

Trends and present conditions in converter steelmaking at the Japan Steel & Tube Co. Ltd T. Kinoshita (*Tetsu to Hagane*, 1960, **46**, July, 788–796).

The decarburization of the pitch-dolomite lining in the basic Bessemer converter and its significance for the life of the lining J. N. Klärbing, A. Latour, and L. Heinen (*Radex Rundsch.*, 1959, May, 517–532) Decarburization of the pitch-dolomite lining of basic converters occurs during holding time after blowing with O_2 from the air entering the converter. Decarburized linings showed a much reduced service life, the depth of the decarburized zone depends on the original carbon content of the mix. The studies described include tests with higher carbon content and a coking of the lining, both were successful in increasing lining life. In order to prevent decarburization, waste gases containing CO_2 were injected into the converter during holding time, this was successful but the use of N_2 was better. Of course the best method of avoiding decarburization is the use of magnesite as it does not contain carbon, but unfortunately magnesite cannot withstand the frequent temp. changes involved in the use of a converter.—T.G.

Productivity of the Thomas Steelworks: Method of calculations used at Differdange M. Schmit (*Centre Doc. Sidér.*, 1960, **17**, (4), 931–933) This short note reproduces the method of calculation used in a survey of plant carried out with a view to operating the converters according to the production programme.

Contribution to the study of the dephosphorization process in the basic Bessemer converter G. Husson (*Centre Doc. Sidér. Circ.*, 1959, **16**, (7), 1555–1566) An attempt is made to explain the observed phenomena of the conversion process in terms of the changes in slag composition which occur during dephosphorization. Various methods of determining the end-point are considered and the value of the 'opacimeter' is stressed. (**Discussion**) ((11), 2399–2402) In the discussion on the use of the 'opacimeter' to control the converter process, the effects of an excess or deficiency of lime are debated.—A.G.

Oxygen converter processes H. F. Padbury (*Refract. J.*, 1960, **36**, May, 118–122) The various processes including LD and LD–AC are outlined and refractory practice and converter wear are considered.

Devanadization of iron in the converter by blowing with powdered oxidants A. N. Lekontsev (*Stal'*, 1960, (8), 701–703) High temp. promotes the oxidation of C and may promote the re-entry of V and Cr. Scale or Fe–V concentrate is blown into side-blown converters giving slags with higher V_2O_5 contents.

Measurement and recording of converter bath temperature, by sighting across the throat, theoretical and practical applications J. Galey (*Centre Doc. Sidér. Circ.*, **16**, (11), 2403–2425) The method of optical pyrometry described gives good agreement with the temp. measured by immersion pyrometry. The form of the temp. curve as a function of the volume of air blown is described and practical consequences are considered.—A.G.

The quality of converter rimming steel melted with oxygen blowing A. P. Gulyaev, A. A. Mitrofanov, and M. A. Volkova (*Stal'*, 1960, (8), 741–745) A long term comparison with OH steel is reported. Composition and mechanical properties were measured and converter metal was found to meet the GOST 380 specification though not so regularly as OH. However, it is regarded as unnecessary to draw up separate specifications for OH and converter steels.

Practical port dimensions for open hearth furnaces N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 715) A note from Chelyabinsk. A study of port design is said to have increased output by 4–10% and reduced fuel consumption by 5–11%.

Effectiveness of using spinellide magnesium oxide roof bricks in open hearth furnaces N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 715) A note from Chelyabinsk. The use of PShS brick instead of magnesite-chrome gives 16·5% less wear but 8% greater heat loss.

Tests on silica bricks of different origins in an open hearth lining J. Vergé and M. Grafteaux (*Centre Doc. Sidér. Circ.*, 1959, **16**, (10), 2221–2241) Three types of silica brick of varying degree of transformation and different chemical analysis were compared in the roof of a working furnace. No significant difference was observed, in agreement with a quality index, total porosity $+20\times Al_2O_3-50$ (absolute density $-2{\cdot}3$) which was similar for all bricks.

Reflections on refining and deoxidation in the Martin furnace M. Husson (*Centre Doc. Sidér. Circ.*, 1959, **16**, No.8, 1774–1776) Discussion of the paper pp.2067–2079 (Oct.).

Determination of the ideal limestone consumption and the development of slag conditions for open-hearth heats N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 715) A note from Chelyabinsk. A method of reducing the limestone used by 4–6% is given.

The operation of a 400-ton open hearth furnace on by-product petroleum oil gas F. D. Voronov, A. G. Trifonov, S. E. Khusid, E. I. Dikshtein, E. V. Val'piter, Yu. B. Snegirev

and V. G. Antipin (*Stal'*, 1960, (7), 594–598) A review of the process of adapting the OH to firing with this gas, the analysis and calorific value of which are given. Large savings are claimed.

The use of silicon-chromium in the melting of steel in open-hearth furnaces M. I. Kolosov, A. I. Stroganov, N. V. Keis, V. F. Bogatenkov, O. Ya. Vainshtein, A. M. Danilov, B. F. Zverev N. G. Antropova, and V. A. Khryukina (*Stal'*, 1960, (7), 607–608) Savings are claimed by the use of Si–Cr in the deoxidation of low-carbon types of Cr steels.

Use of nickelous oxide in melting nickel-bearing steels in open hearth furnaces N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 715) A note from Chelyabinsk. Satisfactory use of NiO in amounts of 250–3700 kg per heat according to grade of steel is reported.

Oxygen in open hearth steelmaking (*Iron Coal Trades Rev.*, 1960, **181**, Aug. 12, 355–362) Papers at the BISRA Junior Steelmaking Conference. **Oxygen as an aid to combustion** J. R. Bell (355–357) Trials at the Redcar works on use for flame enrichment, for decarburization and for refining are reported. **Oxygen for refining at the Redbourne works of Richard Thomas & Baldwins Ltd** A. S. Barker (357–358) Experiments with O_2 lancing are briefly summarized. **Oxygen for pre-refining** E. Davies (358–360) Oxygen lancing in the ladle and the construction of a pre-refining vessel are outlined. **The Ajax process** A. Jackson (360–363) Production figures are given.

Use of oxygen in the burners of the rich fuel O.H. furnaces of the O.H. steelworks at Mont Saint-Martin Mulsant, Galloy, Jouhaud, and Poiré (*Centre Doc. Sidér.*, 1960, **17**, (4), 947–962) Tests carried out during a period of more than a year showed an appreciable rise in furnace productivity of a minimum of 10%. For one furnace studied in more detail in which alternate comparative tests were carried out, the minimum increase in productivity was 28%. This furnace was already overcharged with 80 t for a hearth surface of 22·5 m². Hourly production increased from 320 kg per m² of hearth surface to 400 kg with oxygen. It is concluded that oxygen should be used during the entire furnace campaign.

How oxygen input affects open-hearth steelmaking A. L. Hodge and C. S. Arnold (*J. Met.*, 1960, **12**, April, 325–330) Oxygen sources and distributing efficiency are reviewed and the chemical and thermal effects of a high oxygen input rate are discussed and data analysed.

The use of oxygen in the open-hearth furnace I. Present-day processes E. Füssl (*Radex Rundsch.*, 1959, May, 533–545) A review based on published information of the use of oxygen in OH furnaces with considerations of the financial savings made (12 refs). **II. Application of the processes used in steelmaking with oxygen to the use of oxygen in the open-hearth furnace** W. Schreiber (546–556) The technical similarities existing between the use of oxygen in the converter and in the OH furnace are discussed on the basis of published information. The increase in output of the OH furnaces by the use of O_2 in connexion with the great advantages that the OH furnace offers is emphasized (42 refs).—T.G.

Use of oxygen lances and basic brick in open hearth furnace roofs H. A. Parker and T. Schane jun. (*AISI Reg. Techn. Meetings*, 1959, 305–330) An improved method of introducing gaseous oxygen into the bath, and so reducing heat time, and a type of basic roof construction is illustrated for which, by avoiding wide variation of temp. and giving longer roof life, increased production is claimed. The results are tabulated and compared with those of previous practice. At high operating rates, silica roof life is reduced 10–20% when using oxygen. With basic roofs the life is two–three times that obtained on silica roofs.

The use of scale during steelmaking by the scrap-ore process V. O. Kulikov, M. M. Khil'ko, V. M. Prilepskii, and A. P. Zubkov (*Stal'*, 1960, (8), 708–710) Using mill scale in place of ore reduces limestone consumption, raises slag fluidity and basicity, enables low-S steels to be produced, accelerates slag formation, reduces slag quantity, and makes it easier to remove, with decrease of costs and increase of productivity.

Note on tests carried out for the injection of compressed air into the gas burners of furnace No.4 of the O.H. steelworks of Valenciennes-Usinor with a view to increasing the productivity of this furnace J. Fauchon, J. Serre, and L. Septier (*Centre Doc. Sidér.*, 1960, **17**, (4), 935–946) The conditions under which the tests were carried out are described. In two weeks operation the average gain in hourly production was 11·4%. The average speed of melting increased by 15·5% during two weeks' operation.

Control of flame direction in OH furnaces fired by lean gas L. Septier (*Centre Doc. Sidér.*, 1959, **16**, (8), 1771–1774) The injection of compressed air or steam with the flame is discussed. Increased production and a 10% saving in heat consumption is claimed for this technique.

Open hearth heats intensified by blowing air from compressors into the bath K. M. Trubetskov and M. Ya. Medzhibozhskii (*Stal'*, 1960, (8), 714) A review by the former of a book of this title by the latter. Various minor criticisms of the test are made.

Contribution to the study of open hearth regenerators L. Septier and J. Serre (*Centre Doc. Sidér. Circ.*, 1959, **16**, (10), 2205–2220) Factors governing heat exchange and gas flow in regenerators are discussed and conclusions are drawn regarding ways of improving thermal efficiency, simplifying construction, and reducing refractory wear.—A.G.

An effective layout for regenerator checkers L. M. Lomakin, S. S. Pinkarev, and V. A. Rybnikov (*Stal'*, 1960, (8), 710–711) The two top courses are made of silica brick and the rest of magnesite. The SiO_2 brick is intended to catch the dust. The system is satisfactory for moderate temp. (1 350–1 400° in the later stages of the campaign). Substitutes for magnesite should be sought as it is in short supply.

Recent improvements in cleaning open-hearth checkers (*Iron Steel Eng.*, 1960, **37**, May, 172) A description of the use of high pressure water by Great Lakes Steel Corp. for cleaning their OH furnace hot brickwork checkers. The water is supplied by a portable trailer-mounted rig.

The reliability of visible flame radiation as a criterion of the operation of a Maerz-type open hearth furnace fired with brown coal producer gas A. Friedrich (*Bergakademie*, 1960, **12**, May–June, 305–306) Total radiation measurements and measurement of the spectral distribution in the visible region of 400–660 mμ indicated that neither luminosity nor flame temp. could be used alone to assess flame conditions. The effects of various preheating temp. and tar additions on flame luminosity were examined.

Theory and application of ejector pumps R. Jung (*VDI-Forschungsh.*, 1960, **28**, (479), pp.32) The theory of ejector pumps is developed with the aim of establishing design principles for industrial applications such as ventilation, carrying away waste gases from furnaces, e.g. OH furnaces, etc. Examples of applications are quoted.—T.G.

A change from open hearth to arc electric furnaces W. J. Bolton (*AISI Reg. Techn. Meetings*, 1959, 193–212) A short account of the conversion from OH to electric-arc furnace production in the Seattle, Wash. plant of the Bethlehem Steel Co. between 1956 and 1960, with resultant increased production.

Britain's largest electric arc steel furnaces (*Metallurgia*, 1960, **61**, March, 103–104) A description of the new electric steelmaking plant to be installed by the United Steel Co. Ltd. These furnaces will have a nominal capacity of 150 t and are of Demag design.

Electric furnace operations at Gadsden L. B. Wright (*AISI Reg. Techn. Meetings*, 1959, 361–366) The operation of Republic Steel Corp.'s two 175-t electric furnaces at Gadsden, Ala., is briefly described.

Inductive stirring in electric arc furnaces B. Hanas (*Neue Hütte*, 1960, **5**, June, 323–331) The results of several years' experience with the technique have borne out the satisfactory results of earlier trials. The construction and operation of the equipment are described. Advantages are: the bath is more homogeneous; chemical reactions between steel and slag are accelerated; slagging-off is simplified; and the number of inclusions in the steel is reduced.

Leakage detector for high frequency furnaces Rigollet (*Centre Doc. Sidér.*, 1960, **17**, (5), 1201–1206) This article describes a warning device used for the detection of leakages in high-frequency furnaces. An electrode inserted in the bath, or 2 or 3 cm in the clay, is led down to the ground. This earths the bath and is a protection for personnel manning non-insulated tapping bars. The clay becoming a heat conductor if metal infiltrates to the winding or if the wall thickness is insufficient, a current passes between point B of the coil circuit and the metal. This passes through resistance R, there is a fall in tension which is shown on an ammeter. As soon as the metal approaches the winding or the thickness of the crucible declines to danger level this is shown on the ammeter. When it shows the maximum value the liquid metal must be evacuated as quickly as possible from the crucible.

Production and casting of rail steel A. N. Morozov (*Stal'*, 1960, (7), 610) A note from Chelyabinsk, with the Ashinsk Iron and Steel Works. Impact strength of the M16S steel was low and it was found that the use of more Fe–Si and Al for deoxidation corrected this.

On the nucleation and growth of CO bubbles in liquid steel. Kinetic studies on the steelmaking reaction K. Niwa and M. Shimoji (*Tetsu to Hagane*, 1960, **46**, Jan., 19–24) The reaction between carbon and oxygen in liquid iron is discussed in terms of rate determination by the diffusion film theory. The most reasonable process is transport of dissolved elements to the existing surface of CO bubbles. Nucleation for the bubbles would occur at solid-metal interfaces (14 refs).—K.E.J.

Improving the quality of 18KhNVA steel N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 721) A note from Chelyabinsk. New melting practice reducing H_2 content is indicated.

Development of a melting practice and improvement of the surface of ingots of 1Kh18N9T stainless steel N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 721) A note from Chelyabinsk. Mould dressings were tried, a petroleum-ceresin composition being the best, and fuller deoxidation with Si–Cr and Fe–Cr, with saving in the latter is used.

Improved quality of ball bearing steel N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 757) A note from Chelyabinsk. A new melting technique with a more intensive boil reduces non-metallic inclusions. The composition of 30Kh9SNA steel is critical, any deviations reduce mechanical properties. Heat-treatment conditions are given.

Rational melting practice for the production of ball-bearing steel S. G. Voinov (*Stal'*, 1960, (8), 716–721) A study was made of non-metallic inclusions. Detailed instructions covering melting practice are given for reducing these to a minimum. The method has been in use since 1957 and the great improvements it has produced are shown.

Study of the application of the Gazal process to the desulphurization of iron Lambert and Messin (*Centre Doc. Sidér. Circ.*, 1959, **16**, (10), 2183–2191) The Gazal process involves agitation of metal and slag by compressed air or nitrogen introduced via porous plugs. Trials are reported on the desulphurization of ordinary Thomas irons, the factors studied being silicon content, limestone additions, charge temp., etc. Results suggest that the process is both economic and simple to operate.—A.G.

A practical design for blooming mill ingot moulds D. F. Nagovitsyn (*Stal'*, 1960, (7), 602–607) Tests on moulds with different ratios of height to cross-section showed that the longer and narrower ingots gave better macrostructure and improved homogeneity, reduced top discard, and increased soaking-pit capacity and mill output by reducing the rolling required.

Statistically controlled tests on ingot mould life J. Duflot (*Centre Doc. Sidér. Circ.*, 1959, **16**, (7), 1567–1608) An account is given of methods of quality control applied to ingot moulds. The statistical treatment for sample lots of constant and variable size and also for constant time intervals is described in detail.—A.G.

The origin of transverse cracks and pitting in moulds and methods of preventing these defects

V. G. Malinovskii and A. S. Babii (*Stal'*, 1960, (7), 610) A note from Enakievo. The cooling of the moulds after removal of the ingots has a considerable influence. Air cooling, with use of a graphite dressing and top pouring reduced mould consumption from 23 to 10·8 kg/t steel.

Sand ring formulation for open hearth hot top practice G. M. Corbett and R. H. Cooper (*Iron Steel Eng.*, 1960, **37**, May, 171–172) Refractory rings are made from sand to which is added water-soluble liquid phenolic resin and MgO.

Experience in the production of 10-ton rail steel ingots F. F. Sviridenko, A. N. Popova, M. G. Fradina, A. V. Chernova, and L. P. Tarasova (*Stal'*, 1960, (8), 699–701) Changing to 10-t ingots (from 6- and 8-t ingots) reduced teeming time by 10% and train marshalling by 31%, with saving in soaking pit time and reduced metal consumption in rolling.

Steel teemed from twin-nozzle ladles by remote control P. K. Morokov, I. A. Sokolov, S. P. Kochnev, and I. M. Kurpyaev (*Stal'*, 1960, (8), 704–708) A simple hydraulic stopper control system is shown. With twin-nozzle ladles, if one becomes unserviceable, work continues with the other. An increase in output is claimed besides the safer and better working conditions.

Exothermic sideboards increase ingot yield Allegheny Ludlum Steel Corp. (*Iron Steel Eng.*, 1960, **37**, May, 161) Hot tops are eliminated and two exothermic side-pieces inserted along opposite sides in the heads of wide end down slab moulds. Increased ingot yields, time saving, increased mould life, and the use of wide end down moulds (easier to strip) are among advantages claimed.

Factors affecting temperature drop between tapping and teeming N. L. Samways and T. E. Dancy (*J. Met.*, 1960, **12**, April, 331–337) Statistical equations are derived for expressing the temp. drop between tapping and teeming in the case of an OH and basic-oxygen plant in terms of tapping time, ladle additions, and holding and teeming times, and the results are discussed.

Deformability of slag ladles of different shapes K. A. Pak (*Stal'*, 1960, (8), 695–696) Tests on model ladles of one-tenth linear dimensions were made showing the advantages of exterior ribbing. Strain-gauges were used to measure deformation which was caused by creep at the high temp.

Continuous casting at Terni M. Signora and R. Cardano (*Fonderia Ital.*, 1960, **9**, (6), 265–273) This article describes the plant and its operation at the Terni Company. The plant has a capacity of 150000 t a year and casts billets 140×140 mm. 35–60-t furnaces are used. The main conclusion is that it is necessary to operate the plant to its maximum capacity if the economies inherent in the process are to be fully realized and therefore steelmaking must be speeded up to support the increased rate of production through continuous casting.

Effect of inoculants on the crystallization and sulphur distribution in cast austenitic steel N. S. Kreshchanovskii and I. E. Zal'ludovski (*Metallov. Term. Obra. Met.*, 1959, (3), 33–37) The effect of sulphur in these steels is discussed, and the results of work on the effect of Zr, Ce, and Ca additions to the steel, and of radiographic studies of the distribution of sulphur (in the form ^{35}S) are given.

Louden heavy-duty ingot slicing machine (*Machinery*, 1960, **96**, Feb. 10, 313–314) With description and illustrations.

Ingot defects, a study of the origin and effect H. H. Hartman (*AISI Reg. Techn. Meetings*, 1959, 235–270) Information resulting from an investigation carried out for the purpose of personnel training on the wire mill and seamless mill products of the Colorado Fuel and Iron Corp. is presented and summarized. The defects are illustrated.

FOUNDRY PRACTICE

The use of the Bouken model for the solution of heat transfer problems in foundry practice K.-H. Brokmeier (*Giesserei*, 1960, **47**, April 21, 195–204) The use of Bouken analogy models to determine heat transfer conditions in various aspects of foundry practice is described with examples of the determination of casting temp. and a study of the solidification of melts.

Additives R. W. Heine, E. H. King, and J. S. Schumacher (*Mod. Castings*, 1960, **37**, May, 88–90) The various improvements effected by the use of additives are discussed, particularly the effect on flowability, expansion control, casting finish, and edge and surface hardness.

The role of silicon in the formation of internal chills in cast iron piston rings I. V. Lebedev (*Lit. Proizv.*, 1960, (2), 45) Si reduces the solubility of carbon in iron and increases the eutectic limit. However, the tendency of iron to internal chills increases also. It is therefore impossible to attribute this to any one factor because a variety of causes influence the formation of chills, among which may be counted rate of recrystallization, chemical composition, liquation of the phosphorus and other components, the presence of active graphitization foci, etc.

The relations between wall thickness and the physical properties of grey cast iron A. de Sy and J. van Eeghem (*Giesserei*, 1960, **47**, June 16, 315–323) The relationship between tensile strength, Brinell hardness, and wall thickness were investigated statistically on about 2000 specimens of lamellar graphitic cast iron, the influence of P content being also taken into account. The general validity was also confirmed of Collaud's formula: $\log \sigma_{tx} = \log \sigma_{t30} + 1{\cdot}57 (\log HB_x - \log HB_{30})$ (13 refs).

The use of nomograms in the calculation of the capacities of technological processes exemplified in heavy industry H. Geissler (*Technik*, 1960, **15**, Aug., 517–521) The calculation of the output in the foundry is used as an example for the application of nomograms.—T.G.

Thames foundry of the Ford Motor Co. Ltd (*Refract. J.*, 1959, **35**, Sept., 277–279) A brief description of the design and layout of the new Dagenham foundry on the occasion of a visit by the Silica and Moulding Sands Association.

Lay-out of the mechanised foundry at Nueva Montaña Quijano, S.A. J. Vazquez White and J. Olivieri Rueda (*Anal. Mec. Elect.*, 1960, **37**, Jan.–Feb., 3–16) A full account of the operation of the various sections of the foundry is given. The melting bay contains two cupolas of 4·5–5·5 t/h capacity, a 4-t arc furnace, and two 1-t coreless low-frequency furnaces; there are two moulding sections, a coreshop, a sand preparation unit, and finally, fettling and control. Details of line movement and distribution are shown schematically.—P.S.

Closed circuit vertical step conveyor for foundries A. Ya. Savitskii (*Lit. Proizv.*, 1960, (2), 14–16) A conveyor is described consisting of a fixed and a movable frame and eccentric hoist with pneumatic drive, a drive for the movable frame and guide rollers. All controls are mounted on a console. Drawings and details of electrical circuits are supplied.

Automatic line for moulding, assembling and knocking out castings I. F. Bol'shakov and B. K. Svyatkin (*Lit. Proizv.*, 1960, (1), 16–19) An automatic line is described for making the moulds, assembling them in the casting box, and then knocking out the completed castings. The line is built round the automatic press BIF–1 at the Likhatchev Works in Moscow. It has a production of 230–360 moulds per h. The making time for the moulds in a 450×350×120 mm box is 10–15 s.

Griffin Wheel Co. opens cast iron pipe foundry (*Mod. Castings*, 1960, **37**, May, 196) A description of the plant, the pipe produced, and the activities of the Company.

Seven basic steps assure clean melt H. C. Ahl (*Mod. Castings*, 1960, **37**, May, 212) The purpose of melting and the difficulties involved, are summarized and seven precautions required are given.

Importance of coke size and quality in cupola operation R. Loison, L. Soubrier, and M. Decrop (*Inst. Hierro Acero*, 1960, **67**, May, 488–504, special number) An experimental study of coke properties with respect to cupola operation is reported. Size has the most important influence, a graded coke is better and the larger the size (in the 40–120 mm range at least) the better; the optimum coke size is probably related to the cupola diameter. Shock resistance is important, Micum 80 seems to be a good criterion of coke quality. The relationship between the behaviour of the coke and its reactivity is less clear.—P.S.

An efficient shape for the cross-section of the charge in large cupolas V. A. Fuklev (*Lit. Proizv.*, 1960, (1), 15–16) The increase in the dia. of the cupola beyond a definite limit results in the deterioration of certain melting indices. The shape of large cupolas should be oval, examples are cited of USA cupolas of 1800 mm dia.

The new cupola plant of the Giesserei Institut of the Technischen Hochschule, Aachen W. Patterson and F. Neumann (*Giesserei*, 1960, **47**, April 21, 204–208) The plant described consists of a water-cooled cupola which can be worked with cold, warm, or hot blast. Structural and operating data are given.

The effect of the methods of ethyl silicate hydrolysis on the quality of the refractory lining L. A. Zhitkova (*Lit. Proizv.*, 1960, (1), 20–23) A report of the investigations carried out at the NIITAvtoprom during 1957–8 on the hydrolysis of ethyl silicate to impart to it binding properties. A method of hydrolysis with small quantities of water is suggested. Such hydrolysis solutions have great stability (not less than one year) and while reducing the consumption of ethyl silicate they also shorten the time for hardening by layers from 2·5–3 to 1·5 h.

Low frequency induction furnaces: The design and application of channel and coreless types compared M. G. Gibbs (*Elect. Rev.*, 1960, **167**, Aug. 19, 317–322) A brief historical introduction and description of the types of furnace, including the newer metal crucible type, is followed by a general account of their use in the foundry. Most of the accounts are of non-ferrous applications.

Continuous production of ductile irons using the sensible heat of the castings D. M. Nabrodov (*Lit. Proizv.*, 1960, (1), 38) Tests are described of annealing ductile iron castings in permanent or sand moulds using the sensible heat of the castings followed by speeded-up cooling (by compressed air) and by natural cooling. It was found that speeded-up cooling had little effect on the duration of the anneal, structure, and properties of the metal, and some alternatives for annealing with the sensible heat of the casting are suggested. These have reduced the annealing time to 12–16 h, thus increasing productivity.

Chemical micro non-uniformity of the matrix of ductile irons A. I. Yatsenko (*Lit. Proizv.*, 1959, (1), 30–31) This chemical micro non-uniformity depends to a large extent on the chemical composition of the iron. With Kertch arsenical ores, considerable non-uniformity can be observed in castings as regards the distribution of Si and As. This fact should be taken into consideration when working out heat-treatment processes for such castings because this non-uniformity will reflect on the kinetics of graphitization as well as on the position of the phase transformation temp. during heating and cooling.

The control of graphitization in grey cast iron J. O. Cadellans Oller (*Inst. Hierro Acero*, 1960, **67**, May, 512–520, Special Number) Some examples of the use of the chill test in the control of graphitization of plain and alloy high-strength irons are presented; these tests provide a rapid and reliable control of graphitization.—P.S.

A synthesis of the results of Belgian research into the correlation 'Massiveness, physical properties' of grey cast iron A. De Sy and J. van Eeghem (*Fonderie Belge*, 1960, **30**, March, 76–81) Substantial progress has been achieved in research into the problem of the correlation between physical properties and the massiveness of grey iron castings. The research results are given in this article. A study of the physical properties of the grey iron castings in flake graphite shows the validity of the 'auscultation' method of foundry pieces favoured by A. Collaud and based on the ratio: $\log \sigma$ tx $\log \sigma\, t_{30} + 1{\cdot}57 (\log \Delta_{30} - \log \Delta_x)$. The ratio is however not valid for thin-walled pieces (<6 cm) as the graphite often changes form in relation to the type of graphite in the notched bar of 30 mm dia.

Influence of various inoculants and treatments on structure of nodular cast iron R. K.

Cleworth and J. F. Wallace (*WAL* 331, 1/10; *PB* 127570, 1950, April, pp.34; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 123; no abstract).

Experiments on the inoculation of iron with cerium alloys E. M. Shkol'nikov, L. G. Bondarenko, V. A. Zakharov, and N. P. Chichagova (*Lit. Proizv.*, 1960, (2), 36–37) Investigations are reported on the use of mischmetal jointly with Mg or with Mg alloys. These are based on the experience gained in Britain and the USA. The inoculations were carried out with Fe–Ce of type FTsM with additions of up to 10–20%Mg.

Intracrystalline liquation of silicon and magnesium in iron with spheroidal graphite M. A. Krishtal, E. P. Rikman, and A. A. Zhukov (*Lit. Proizv.*, 1960, (2), 28–31) The non-uniformity of Si and Mg distribution may be corrected by heat treatment and some suggestions are made. A reduction in the Si content should be accompanied by an increase in the carbon content up to the eutectic limit so that the increase in the quantity of spheroidal graphite may increase the dynamic characteristics. Mg iron should be considered not only a substitute for a number of existing ferrous and non-ferrous materials but also as a structural metal possessing some valuable qualities: strength, plasticity, antifriction properties, resistance to wear, etc.

Regarding the brittle and plastic state of s.g. cast-iron N. G. Girshovich and M. P. Simanovskii (*Lit. Proizv.*, 1960, (1), 25–30) The chemical non-uniformity of the matrix of ductile irons depends chiefly on the composition. In the industrial ductile irons made from Kerch ores containing arsenic, considerable non-uniformity can be observed in the distribution of Si and As. This should be taken into account when working out methods of heat treatment, otherwise this non-uniformity will reflect on the kinetics of graphitization and on the temp. of the phase-transformations during heating and cooling.

Is there a shrinkage of the cast iron with the abnormal appearance of spheroidal graphite? I. Przhibyl (*Lit. Proizv.*, 1960, (2), 22–25) Sulphur-containing cast iron of a definite composition do not show shrinkage, while s.g. cast iron of the same composition shows greater shrinkage than all other forms. This shrinkage is greater with a lower casting temp. This study aims at clarifying the effect which all the factors may have on this behaviour and certain preliminary conclusions are pointed out.

How small quantities of zinc affect cupola malleable iron J. Pelleg (*Foundry*, 1959, **87**, Nov., 168–170) Industrial scale tests have been made to assess the suitability of Zn-bearing scrap for the production of malleable iron. The results show that Zn well in excess of 0·2% can be tolerated due to the degree of oxidation in the cupola.—A.G.

White iron growth during malleablizing N. R. Kelley and B. A. Ruediger (*Mod. Castings*, 1960, **37**, May, 95–110) The authors describe work done to determine the cause of growth during malleablizing. They showed, within the limits of their study, that decarburization substantially retards growth, while in the absence of decarburization, carbon content determines growth, while annealing variables have no effect on it. It was also shown that the smaller growth of white iron during gravel pack-annealing is due to decarburization.

Core chaplets for malleable cast iron F. Iske and W. Mainz (*Giesserei*, 1960, **47**, June 2, 301–304) A general review of the use of core chaplets and the associated danger of scrap is followed by a discussion of the possibilities of removing the danger of cracking in malleable iron castings by suitable chaplet design.

Quickly hardening mixtures for large steel castings N. N. Polodurov (*Lit. Proizv.*, 1960, (2), 39) Components up to 8·2 t are cast at the foundry shop of the Dnepropetrovsk Works with rapidly hardening mixtures, for example a cylinder for a hydraulic press tested at 420 atm. Some types of mixtures for rapidly hardening layers of up to 30–40 mm thickness are given together with their physical and technical characteristics.

Steel founding (*Mét. Const. Méc.*, 1960, **92**, July, 531–537) A study made by the Association Français des Aciéries de Moulage with a view to informing manufacturers of the rules to be complied with in making drawings of parts, so that founders may supply them with faultless castings. Founding principles and processes are reviewed and rules on drawing are given.—S.H.-S.

Achieving ultra-high strength in low alloy steel castings R. H. Herrmann (*Foundry*, 1959, **87**, Nov., 90–94) Through the use of high purity raw materials and a ceramic cope and drag mould with extensive risering, complex castings may be produced with ultimate tensile strengths up to 300 000 psi. Some examples of typical parts are given.—A.G.

Foundry problems arising from the construction of modern hydraulic turbines J. Goffart (*Fonderie Belge*, 1960, **30**, April, 99–104) This article deals with some of the problems the foundryman has to solve in producing large parts in martensitic steel. After examining the effect of corrosion on various types of stainless steels the writer concludes that Cr martensitic steel is the best for hydraulic turbines. He discusses the metallography, heat treatment, repair welding, casting, and melting of the same steel.

Study of steelworks sands and their use J. Duflot and J. Vergé (*Centre Doc. Sidér.*, 1960, **17**, (5), 1207–1257) This article presents the results of a questionnaire sent to French works designed to compile a list of sands and their suppliers, the required sand characteristics, and the best conditions for their use, to compare methods used by works to make the linings, to compare the results obtained with the various sands and to establish which sands can compete with foreign products.

Sand segregation, causes and effects T. W. Seaton (*Foundry*, 1959, **87**, Nov., 86–89) The harmful effects of sand segregation on foundry practice are discussed and recommendations are made on methods of handling to minimize such segregation.—A.G.

Pushbutton system mixes sand automatically F. R. Morey (*Foundry*, 1959, **87**, Nov., 98–101) In the installation described any combination and quantity of various sands may be automatically prepared for distribution throughout the foundry. Weight control is effected by load cells and the composition of each batch is permanently recorded.—A.G.

Synthetic moulding sand for grey iron foundries O. Gerstmann (*Giessereitechn.*, 1960, **6**, (3), 86–88) Experiments on synthetic sands from constituents available in Eastern Germany are described, and examples given of their use.

Continuous automatic mulling J. H. Schaum (*Mod. Castings*, 1960, **37**, May, 82–86) The advantages of electronic moisture control in mulling are described. Not only is it possible to dispense with some labour, but also the moulding sand mixture content is very accurately and consistently controlled, leading to improvement in mould properties.

The future of river sands in the foundry industry A. A. Gorshkov and B. I. Markhasev (*Lit. Proizv.*, 1960, (2), 2) Investigations are proceeding in order to establish the suitability of river sands in the foundry industry. These sands are characterized by their low clay content, less than 0·5%, and high silica content. Extraction is very easy and the cost per t amounts to 12–13 rbls., i.e. cheaper by a factor of 2–2·5 than from sand pits.

Physical and technical properties of ore and zirconium sands, also of enrichment wastes A. N. Taibrik (*Lit. Proizv.*, 1960, (2), 38) Investigations carried out at the Foundry Research Institute have confirmed that Zr and ore sands have very valuable physical and technical properties. The huge Ukrainian deposits must be investigated. Sands from the treatment of mineral ores have different concentrations of minerals among which is Zr also, and sands resulting from different enrichment operations, the so-called tailings, are very useful. Different types of these sands are marketed under special classifications and the corresponding specifications are listed.

Modernization of a sand blowing machine type 287 E. I. Talanker (*Lit. Proizv.*, 1960, (2), 42–43) The original type is used for the preparation of cores, but since it needs a great deal of adjustment it is used relatively rarely. Certain alterations have been carried out, chiefly in the slide valve controlling the openings in the bottom through which sand is blown. Changes in the electrical control system have also been introduced and diagrams are given.

The binding mechanism in moulding mixtures D. S. Williams (*Lit. Proizv.*, 1960, (2), 26–27) This study made at the University of Ohio, USA, considers some of the factors responsible for binding the mixtures, mainly the formation of polar bodies, their combination, absorption, and the resulting hardening.

Apparatus for measuring the hardness of the rammed mixture for tube moulds A. N. Smolyakov and G. A. Sizonenko (*Lit. Proizv.*, 1960, (1), 41–42) An apparatus is described for measuring the hardness of the internal surface of the moulds used for centrifugal castings. This type of hardometer (Soviet patent 116889 of 1958) is recommended for checking the quality of moulds.

The gas permeability coefficient W. Eger and W. Bohn (*Giessereitechn.*, 1960, **6**, (3), 81) Gas permeability is defined, and an expression $D_s = \frac{QH}{F.t.p.}\left[\frac{cm^2}{min\ cm\ WS}\right]$ for the 'gas permeability coefficient' D_s is derived and discussed.

Penetration of moulding sands by low melting point metals K. Fursund (*Inst. Hierro Acero*, 1960, **67**, May, 460–487, Special Number) Because of various side effects and other difficulties inherent in the investigation of molten iron penetration of sands, low melting-point alloys (usually 8 and 17%Bi–Sn) have been used to determine the fundamental physical conditions of metal penetration. Details of the apparatus used and results obtained are supplied. It is concluded that: (a) metal penetration of sand takes place under the same physical laws for iron and steels as for the low-melting-point metals; (b) the surface tension of the metal, the pore size of the sand, the equilibrium conditions during penetration are, together with the thermal conditions, decisive with respect to the speed and depth of penetration; (c) there is a considerable temp. difference between the sand and the metal penetrating it; and (d) the increased speed and depth of penetration with greater metal pressure is mainly due to the fact that penetration is stepwise and the size of the steps depends on the metal pressure.—F.S.

Plaster moulds for casting. I. Linear change of mould dimensions on heating C. Mitsuki and T. Ito (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1960, **9**, March, 124–131) Effects of moisture content, quantity of sand, and addition of salts were noted.

Replacing dry patterns by wet sand patterns which are subsequently coated I. M. Tkachenko (*Lit. Proizv.*, 1960, (2), 39) The production of castings with clean surfaces in normal green sand patterns depends on the applied coatings. A non-aqueous coating is suggested which consists of 20% black graphite, 20% silvery graphite, 50% petrol or kerosene, and 10% fuel oil. For thin-walled castings up to 3% dextrin or up to 2% refractory clay should be added.

The production of patterns and cores in iron foundries with water-glass mixtures S. E. Borukson, V. A. Maslov, and K. M. Ryakhin (*Lit. Proizv.*, 1960, (1), 12–13) Different formulae are given of mixtures for patterns and cores for the casting of up to 350 kg among which (in % of weight) 97% quartz sand type 1KO20A, 3% moulding clay containing 6% of its weight of water-glass (1·48–1·53 sp. gr.), and 0·5% fuel oil (in excess of 100%). The resulting mixture has a permeability of 120–150 units, a green compression strength of 0·2–0·3 and when dried, 3–5 kg/cm^2 with a 3–4% humidity.

Semi-automatic moulding press for investment patterns N. A. Shubin and E. M. Lutovinov (*Lit. Proizv.*, 1960, (2), 44–45) A new press is described with a rotating table attached. This makes it possible to place a much larger number of patterns in the box than is possible with a vertical arrangement.

Preparation of ceramic cores for investment casting I. D. Abramson (*Lit. Proizv.*, 1960, (1), 4–7) Al_2O_3 obtained from bauxite as a powder

consists chiefly of γ-Al_2O_3 and $Al(OH)_3$. For cores, only the α-modification is required, into which γ-Al_2O_3 is transformed when heated. The chief role in this transition is played by the mineralizer, for which certain fluorides or chlorides are used and also the oxides of some metals. The method described permits the manufacture of cores of very great thickness and intricacy of shape not only for hollow castings but also for precision casting of heat-resistant components.

Ladle with a slag collecting notch V. P. Motov (*Lit. Proizv.*, 1960, (1), 42) At the foundry shop of the Ibredsk Combine a pouring ladle is in commission with a welded frame of angles and strip in which an insertion can be introduced constructed of refractory clay and sand. This can easily be repaired and also replaced by a spare notch.

Shape and size of gating systems for permanent-mould grey iron casting G. Schwarz and D. Junghans (*Giessereitech.*, 1960, **6**, July, 207–213) Gating and risering for permanent-mould grey iron castings are explained and illustrated.

Risering of castings J. F. Wallace (*Foundry*, 1959, **87**, Nov., 74–81) Consideration is given to the general requirements of risers to eliminate shrinkage defects in castings. Graphical data is presented on riser volume and dimensions in relation to casting shape factors.—A.G.

Risers or air holes A. Mal (*Fonderie Belge*, 1960, **30**, April, 105) This note describes a method of evacuating air and casting gases from casting moulds.

The use of hyperatmospheric pressures in the feeding of steel castings E. T. Myshkowski (*NRL M*-3148; *PB* 129167, 1957, July, pp.20; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 121; No abstract).

Universal reversing table with automatic arrangement for a moulding machine I. S. Sychev (*Lit. Proizv.*, 1960, (1), 19–20) A reversing table at the Kirov Plant in Kharkov serves at the same time as bottom plate to the moulding machine. It has openings drilled right through in chess-board fashion for the centring of the moulds. A description with drawings is appended.

Dielectric ovens provide fast, even drying to cores M. B. Milonski (*Mod. Castings*, 1960, **37**, May, 221) The use of these ovens is described, and their advantages and disadvantages are summarized.

The baking of foundry cores in the field of electrical capacitors E. Schulz (*Giessereitech.*, 1960, **6**, July, 199–204) The principles of drying in the field of an electrical capacitor are explained and the advantages offered by this method stressed. An oven is described for drying about 500 kg cores per h at frequencies between 5 and 15 Mc/s at a power input of 15–30 kW. Drying time is 2–3 min.—T.G.

Production of iron and steel castings with moulding mixtures with water-glass, without carbon dioxide hardening V. V. Gusev (*Lit. Proizv.*, 1960, (1), 14–15) Formulae are given for a few moulding mixtures dried in air, without blowing with CO_2.

Universal core box for spherical cores V. M. Krivushin (*Lit. Proizv.*, 1960, (1), 43) At the Kolomensk works producing heavy lathes, a universal core flask has been evolved which renders possible the rapid preparation of standard spherical cores. It consists of two boxes, one up to 300 mm and the other from 300 to 500 mm in height. The first is used mainly for cores for open moulds (flanges, sleeves, etc.) of dia. between 25 and 200 mm and the second for 300–500 mm high cores for casting in sand or in boxes of antifriction iron and also in standard moulds.

Coating and drying unit for castings S. Ya. Leonov (*Lit. Proizv.*, 1960, (1), 45) In the foundry shop for sulphur cast iron at the Likhachev plant a machine for painting and drying has been commissioned, which is attended by only two operatives. These attend only to charging and unloading the unit. The output is about 3 t/h. It takes castings of up to $400 \times 400 \times 400$ mm, drying temp. 60–70° in 5–10 min, steam pressure 3 atm.

Effect of atmospheric moisture and time of storage on the compressibility of cores produced by the CO_2 process I. Bindernagel (*Giesserei*, 1960, **47**, Aug. 11, 423–427) The effect of atmospheric moisture on the compressibility of water-glass-bonded cores with time was studied. While the cores in direct contact with water take up considerable quantities with consequent loss in compression strength, drying of the cores was found during storage air even if the relative humidity was high (90% at 20°). This drying process increases or reduces the strength of the cores depending on the chemical composition of the water-glass used.

Novel core and mould production methods using Didi glue KP L. Chroszcz and W. Konig (*Giessereitech.*, 1960, **6**, July, 204–207) Didi glue KP is a glue used for woodwork and is produced in Eastern Germany at Piesteritz. It is a synthetic product on a thiourea dicyandiamide-formaldehyde basis and is auto-setting. Silica sand-glue mixes 97:3 are used. Heating to 160° accelerates curing considerably. Some examples of applications are quoted.

The service life of mould linings A. G. Kolesnichenko (*Lit. Proizv.*, 1960, (1), 39–40) In extensive tests, the most resistant linings were found to be those consisting of three layers: the upper layer being a soot coating of small thermal conductivity, the middle layer a highly refractory graphite coating, and the bottom layer a heat-insulating refractory lining ensuring tight adhesion to the walls of the mould.

Large steel casting in record time English Steel Castings Corp. Ltd (*Found. Trade J.*, 1960, **109**, Aug. 11, 177–178) An account of the casting of a 180-t mill housing for an Al rolling mill.

Manufacture of a heavy table of GG–26 by the cement-sand moulding process F. Meier, H. Giese, and E. Netzmann (*Giessereitechn.*, 1960, **6**, (3), 70–74) Details are given of the pattern making, moulding, pouring, and fettling of a 37 000-kg table made at the Ernst Thälman works of VEB Schwermaschinenbau.

Studies of wheel centre castings H. Shimada (*Bull. JSME*, 1959, **2**, May, 238–244) Tests for the purpose of preventing shrinkage cavity, as carried out on centres of eight-armed steel castings for rolling stock of the Japanese National Railways, and performed in the light of Pellini's experiments, are described, and conclusions as to the result of γ-ray inspection are given.—S.H.-S.

Affecting the Brinell hardness and structure of slideways in machine-tool castings. II K. Wüllenweber (*Giesserei.*, 1960, **47**, Aug. 11, 427–436) After discussing the requirements expected of slideways in cast machine tools the author reports on experiments for establishing the best method of chilling. He found that cast iron chills were too harsh, the best structure combined with high hardness was obtained with silicon carbide chills.—T.G.

The casting of corrosion resistant components of iron–nickel–molybdenum alloys I. N. Yukalov (*Lit. Proizv.*, 1960, (2), 9–10) Alloy EI 461L has a chemical composition of 24–32%Mo, 3–7%Fe, $\leqslant$1%Cr; $\leqslant$1%Si; $\leqslant$1%Mn; $\leqslant$0·12%C; traces of S and P, remainder Ni. To increase corrosion resistance, up to 4%V or up to 2·5%Co should be added. With a content of over 6%Fe in the as-cast condition, corrosion resistance decreased. Below 30%Mo, corrosion resistance also decreases in boiling HCl acid.

Contribution to knowledge of Fe–Al alloys E. Hugony and C. Garino (*Alluminio*, 1960, **29**, (7–8), 339–350) After giving an account of the development and characteristics of Fe–Al alloys, the results of tests carried out in a hot condition and in a sulphurizing atmosphere are described. Cast irons of both low and high Al content and with steels of medium Al content were used. The difficulty of producing these metals in the foundry should be overcome due to recent improvements in melting and casting techniques using the reduced pressure or controlled atmosphere furnaces. As a result of tests carried out the authors now produce on an industrial scale two types of pearlitic Al–Cr irons and some important structural properties of ferritic and Al steels have been established.

Iron for casting alkali-resistant boilers K. I. Vashchenko, A. N. Firstov, P. V. Avrinskii, V. L. Neselovskii, and V. V. Zhizhchenko (*Lit. Proizv.*, 1960, (1), 7–10) As a result of extensive tests a Mg-iron with 2·0–2·2%Si may be recommended, but the technology of casting for boilers is considerably complicated by the thermal treatment, since the quality of the casting is just as important as the chemical composition and the structure of the cast iron.

Machine parts manufacture by precision casting K. Suzuki (*Sumi. Met.*, 1960, **12**, Jan., 368–379) A review.

The fluidized bed for investment castings F. C. Quigley and E. DeLuca (*Mod. Castings*, 1960, **37**, May, 92) This method of applying particle coatings to precoated wax patterns is described, and the advantages of the process, particularly those of speed and even coating of complicated patterns, are pointed out.

Attempts at reducing rejects in investment casting I. M. Stavinskii (*Lit. Proizv.*, 1960, (1), 44) The method of applying the second and the following coats on a base of ethyl silicate by immersion of the blocks of patterns is very labour-consuming and in addition is imperfect because of the formation of air spaces between the first and the subsequent coatings. Better results are obtained by the immersion of the blocks before the application of the first and second coats. Only 5–10 sec are sufficient to hold the blocks over the bath to drain the excess liquid. A first immersion in hydrolized ethyl silicate eliminates these defects and produces a more uniform coating.

Calcining the mould in the flask for investment casting without filling it A. G. Titov (*Lit. Proizv.*, 1960, (1), 41) The roasting is carried out on a holder in which the moulds are clamped in a special recess. The temp. should not exceed 700°. This method has considerably increased productivity.

Methods of casting specimens for the mechanical control of the properties of castings made by the investment process Yu. A. Nekhendzi and M. T. Bogdanov (*Lit. Proizv.*, 1960, (2), 2–6) Observations carried out over a period of years on over 10 000 castings of carbon steels (0·35%C), low-alloy structural steels of type 30KhGSL, high-alloy stainless, acid, and heat resistant steels, etc., as regards quality control are summarized and suggestions made for the casting of the control specimens.

Vertical centrifugal casting machine D.M.M. (Machinery) Ltd (*Brit Steel.*, 1960, **26**, Feb., 53) A description of a machine of Dutch manufacture, designed for the production of cast solid or cored bars of ferrous and non-ferrous alloys.

Chemical non-uniformity of centrifugal steel castings N. N. Reutov (*Lit. Proizv.*, 1960, (1), 35–36) The greatest non-uniformity is observed in slow spinning moulds. At 300–600 rpm the liquid iron does not adhere to the walls but detaches itself and drops off. To increase chemical uniformity the rate of spinning should be increased and methods adopted to delay the rapid formation of a solid shell.

Mechanization of the opening of moulds for centrifugal casting Ya. Ya. Lychagin (*Lit. Proizv.*, 1960, (2), 41–42) A rotating platform is described on which the moulds are placed for centrifugal casting. The platform is provided with a special mechanism in the form of an arm under which the moulds are placed in turn for opening.

Shell cores after Croning H. Petrusch (*Giesserei*, 1960, **47**, July 10, 395–400) The manufacture of shell cores by the Croning process, the moulding tools and shell materials employed, are described and examples of application of these shell cores quoted and illustrated.—T.G.

Shell mixing processes and equipment J. Albanese (*Mod. Castings*, 1960, **37**, May, 111–114) A review of the various shell mixing processes available to the foundryman. The merits of the various processes are discussed and phenolic resins and sand testing are considered in this context.

X-Ray cinematography of the flow of metals in shell moulds, using an image intensifier K. Shobayashi and K. Okamoto (*Inst. Hierro Acero*, 1960, **67**, May, 455–459) (Special Number) Details of the technique are given and stills from two films showing the process of casting in two cases are given; one sequence showed an unexpected flow pattern. A 200 kV X-ray tube, with a photoelectric intensifier giving a 600-fold increase in brightness, was

used. A film speed of at least 64 frames per sec is recommended for photography of the molten iron.—P.S.

Some casting defects, their causes and cures. II H. Williams (*Castings*, 1960, **6**, June, 33, 35, 37–46) Based on the paper by J. L. Francis and S. J. Rogers.

The appearance of flaws in investment castings N. N. Lyashchenko and B. B. Gulyaev (*Lit. Proizv.*, 1960, (2), 31–33) Of the total output of castings of the foundry shop of a large motor-cycle factory, rejects amounted to 10%. An analysis showed that these consisted of about 13% incomplete castings, 61% clogged pouring systems, 13% pipes, and only 13% of the total rejects were due to other causes. The different conditions of casting have been investigated and some suggestions are made for preventing some of these defects.

Surface purity of castings A. D. Popov (*Lit. Proizv.*, 1960, (1), 36–37) The chief factors causing burns on the surface of the castings are pointed out and suggestions made to prevent them. Special coatings are suggested for green sand moulds, and for dry moulds and cores.

The effect of some properties of the moulding material and several other factors on the surface roughness of cast aluminium–silicon alloy and cast iron P. Schneider (*VDIZ*, 1960, **102**, Aug. 1, 1072) This is a brief summary of a thesis. A full account of the study was published in *Giesserei Tech. wiss. Beihefte*, 1959, (26), 1429.—T.G.

An unusual cause of rejection W. Göschel (*Giessereitechn.*, 1960, **6**, (3), 84–86) The cause of the appearance of cavities in heavy V-guide ring castings is discussed, and an improved design suggested.

Failure of castings caused by shrinkage stresses during crystallisation as related to composition A. A. Bochvar and Z. A. Sviderskaya (*Izvest. AN Otdel. Tekhn.*, 1947, (3), 349–355) The examples are non-ferrous.

Repairing defects in iron castings K. M. Zeifer (*Lit. Proizv.*, 1960, (1), 44) Brief indications are given for welding up defects by the oxy-acetylene flame, by the electric arc and using ac.

Liquation of phosphorus and the formation of the phosphide eutectic in irons Ya. N. Malinochka (*Lit. Proizv.*, 1960, (1), 32–33) The investigations here reported have shown that the formation of the phosphide eutectic in normal irons is the result of a strong intercrystalline liquation of the phosphorus which decreases with increasing rate of iron crystallization. With a low rate of crystallization the phosphide eutectic is eliminated even when its content amounts to only 0·05–0·06% and possibly less. Considerable errors may occur in determining the P content in slowly cooled castings due to local concentrations in the islands of phosphide eutectic. An average of a few determinations should be obtained in such cases.

Parameters for casting in permanent graphite moulds M. N. Sosnenko (*Lit. Proizv.*, 1960, (2), 34–36) A study carried out at the Moscow electrode works to establish technical and structural parameters for this method of casting. The results from the extensive investigations regarding chemical composition, casting temperatures, shape etc., are set out.

Control of quality during moulding E. Ruiz Palá (*Inst. Hierro Acero*, 1960, **67**, May, 505–511, Special Number) In order to provide statistical control of quality the author establishes correlation curves between mould hardness, permeability, and strength for given moisture contents, which enable upper and lower permissible hardness values to be fixed. Working between these limits provides stable and acceptable production.—P.S.

New casting dressing shop for pump manufacturer (*Metallurgia*, 1960, **61**, March, 105) A description of the new shop at the works of Lee, Howl, and Co. Ltd.

Professional training in the foundry M. D. Saenz de Tejada (*Inst. Hierro Acero*, 1960, **13**, April–June, 604–609) Details of a typical three-year training programme for apprentice moulders are discussed. Reasons for the shortage of skilled moulders and ways in which this can be overcome are considered.—P.S.

VACUUM METALLURGY

Vacuum melting for tool and die steels K. M. Carlson (*Prec. Met. Mold.*, 1960, **18**, June, 35) Vacuum melting has greatly contributed to improving the quality of tool and die steels due to the improved ingot structure, superior cleanliness, and elimination of undesirable gases and other inclusions. Fatigue life of bearings has reportedly improved by 30 to 100%. With the advent of vacuum arc melting further quality improvement may be expected. Studies are now being carried out to establish the importance of vacuum arc melted tool steels in such applications as precision rolls, extrusion dies, high-speed cutting tools, and die casting dies.

The state of metal melts E. Scheil (*Berg. Hüttenmänn. Monatsh.*, 1960, **105**, June, 131–133) This is a summary of lecture delivered to a symposium on vacuum melting and casting of steel dealing with the theory of the state of liquid metals. Such effects as supercooling, surface tension, and nuclei formation are included.—T.G.

Vacuum stream degassing for the production of castings and forgings V. Scalise, A. De Negri and V. Picardi (*Fonderia Ital.*, 1960, **9**, (6), 257–264) The vacuum casting process has played a great part in eliminating defects due to gaseous inclusions—particularly H_2, in large forgings and castings. This article describes vacuum casting at the SIAC Company at Genoa–Cornigliano describing two methods of vacuum casting used—vacuum ingot casting and vacuum ladle casting. The practical results are given.

The first decade of industrial large-scale vacuum-degassing of steel (*Neue Hütte*, 1960, **5**, July, 383–398) A comprehensive, illustrated review of the various methods used for the degassing of steel on an industrial scale (50 refs).

REHEATING FURNACES AND SOAKING PITS

The use of recuperative soaking pits with liquid slag removal A. I. Sergienko, A. P. Likhoradov, V. I. Gubinskii, and A. I. Babanin (*Stal'*, 1960, (8), 763) Practice at Krivoi Rog is described. The pits hold 100 t of ingots weighing 4–8 t each. Slag runs off at 1360° and amounts to 10 kg/t. A magnesite–chrome lining is used to support the ingots, 10 t are used on repairs which are carried out every 6–8 months. The burners used are described.

Forging and heat treatment furnaces (*Mét. Constr. Méc.*, 1960, **92**, July, 549–550) The use of the Salem–Brasius revolving reheating furnace (of which 100 units are in operation for Soc. CFI) is briefly described, with observations on heat-treatment furnaces, their charging, heating, and temperature regulation.

Heating facilities for the Youngstown Sheet and Tube Co.'s new seamless mill F. C. McGough (*Iron Steel Eng.*, 1960, **37**, May, 123–129) The construction and control equipment are described of the rotary hearth furnace, the roll-down reheating furnace, and the walking beam normalizing furnace installed at the No.3 mill of the Indiana Harbor works of Youngstown Sheet and Tube Co.

An investigation of the heating and rolling of ingots and slabs of transformer steel F. A. Ksenzuk, V. N. Lola, and N. V. Pal'chik (*Stal'*, 1960, (8), 738–739) Practice at Zaporozhstal' is described. Increases in rate of heating and in pit temp. have shortened the time taken without lowering surface quality. Slab heating conditions for satisfactory rolling are given.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Controlled atmospheres. VI (*Trattamenti Term.*, 1959, **2**, Sept.–Oct., 20–21) This article describes a method of heat-treating certain high speed tool steels by superheated steam. This results in the formation of a very hard oxidized film on the metal surface which is very desirable and does not flake. Treatment of normal steels and pig iron by this method increases their corrosion resistance and is less costly than other methods. **VII** (1960, **3**, Jan.–Feb., 25) This final article summarizes briefly recommendations as to the choice of the controlled atmosphere to be used in annealing tempering and brazing various steels and other metals.

Refractory thermal insulation of heat treatment furnaces with special reference to controlled atmosphere furnaces E. Rocco (*Trattamenti Term.*, 1959, **2**, Nov.–Dec., 9–14) Experiments on refractories show the negative effect of iron oxide on refractory bricks in general and insulating refractories in particular, and its effect on the behaviour and life of controlled atmosphere furnace linings either by catalytic action in dissociation of the CO and consequent disintegration by deposit of C, or by partial or total reduction to FeO and consequent increase of plastic deformation under stress at sufficiently high temp. It is therefore necessary to choose refractories with the minimum ferrous content—if possible of the white deferrized type.

Modification of the cast structure of high-speed steel–Prespheroidizing G. Hoyle, E. Ineson, A. Hollingsworth, and D. B. Hammond (*Iron Coal Trades Rev.*, 1960, **181**, Aug. 12, 365–364) Based on BISRA reports.

The future of salt bath furnaces G. E. Stempfel (*Trattamenti Term.*, 1959, **2**, Nov.–Dec., 5–8, 23) The author describes the various applications of salt bath furnaces and gives reasons for maintaining that they still have a future both in conventional and in new applications. He admits that for medium and high-depth case hardening and in cyaniding the use of salt baths is declining, but for the treatment of non-alloyed and alloy constructional steels and special tool steels he considers the salt bath treatment is to be preferred. New uses in prospect include brazing and preheating of ferrous metals and particularly of light alloys.

On the heat treatment of dies (*Trattamenti Term.*, 1960, **3**, Jan.–Feb., 23–24) The most important problem in the heat treatment of dies is to know how long to leave the die in the furnace, i.e. when is austenitation complete? One method is to compare the temp. of the die with a piece of similar size and quality which is treated in the same way and into which a thermocouple is inserted. This method is briefly described with the aid of diagrams.

Heat-treatment of Mn–V–Mo age hardenable austenitic steel N. C. Howells and E. A. Lange (*Mod. Castings*, 1960, **37**, May, 115–119) The heat-treatment of these steels has been investigated, and the conditions necessary to develop the full potential yield strength are given. The relationship between UTS and yield strength has also been determined.

Organisation and management in a modern commercial heat treating plant B. Jousset (*Trattamenti Term.*, 1959, **2**, Sept.–Oct., 3–9) The criteria for decisions regarding the type of stand and layout are discussed with special reference to plant and practice at the authors' company, the Société Parisienne de Cementation. Works transport, general services, and social relations are also dealt with.

The heat-treatment department of a large gear factory J. Lotter (*Trattamenti Term.*, 1960, **3**, March–April, 9–14) This article deals with the heat-treatment of gears at the Milwaukee Gear Company. The plant described included two Super-Allcase controlled atmosphere furnaces, a chamber type of the Foo-Aire horizontal type, a round section type furnace for tempering with a spray cooling device with temp. control, a gas generator, a BX controlled atmosphere generator of 2400 CFH capacity with automatic control of the Autocarb type, and a device for automatic control of the dewpoint for use with one of the Super-Allcase furnaces. The factors influencing choice of plant and layout are described.

Automatic heat-treatment of bearing rollers (*Metallurgia*, 1960, **61**, March, 122) The new automatic heat-treatment plant of British Timken at Daventry, is described. Roller bearings are produced for British Railways rolling stock.

Special features of the heat treatment of machine parts made of G 13 L steel V. I. Sivak and M. A. Tylkin (*Stal'*, 1960, (8), 754–755) The steel has 1–1·3%C, 11–13%Mn and is used for crushers and in blast-furnace and sinter machine parts and is difficult to machine.

As-cast it is austenitic with carbide inclusions which dissolve in hardening. The process of hardening and quenching is given.

Minimizing distortion O. Liedholm (*Trattamenti Term.*, 1959, **2**, Sept.–Oct., 10–13, 26) Deformation in the course of hardening of gears in the car industry requires special precautions. The author considers the steel industry must produce new alloys with different degrees of hardening. He describes tests of a Mn–Mo steel at Volvo of the following composition: max. 0·9%Mn, 0·5%Cr, ~0·8%N, ~0·35%Mo. The effect of various alloys on the surface content is illustrated graphically, based on experience in Sweden and at Climax Molybdenum in the USA.

Remarks on the technique of case-hardening steels in the United States H. U. Meyer (*Schweiz. Arch.*, 1960, **26**, June, 244–245) A brief review of American practice in working with case-hardening steels.—T.G.

Fundamental study of gas carburizing W. T. Groves (*Trattamenti Term.*, 1960, **3**, March–April, 3–6) This article is the first of a series on the theory and practice of gas carburizing.

Determination of the depth of the case and of carburizing of case-hardening steels H. Tauscher and E. Stecher (*Neue Hütte*, 1960, **5**, July, 406–414) The difficulties encountered in the determination of the depth of case and of carburizing are discussed and a reference hardness (HV = 500 kg/mm²) suggested which should be regarded as the limit of depth of case, taken at a distance perpendicular to the surface (20 refs).—T.G.

Depth of hardness in cold-rolling rolls after flame-hardening A. Rose and L. Rademacher (*Stahl Eisen*, 1960, **80**, Aug. 18, 1148–1160) It is shown that a Cr-alloyed steel is more sluggish with respect to transformation than a Mn steel, the Cr steel is therefore better hardenable. Measurements were made to establish the temp. distribution in the outer zone of roll for complete austenitizing treatment. The depth of hardening is restricted by the risk of overheating, the max. depth achieved was 175 mm for the Cr steel (2%Cr) and 100 mm for the 1%Mn steel.—T.G.

Practical hints on the occasional hardening of small metal parts M. Tossi (*Trattamenti Term.*, 1960, **3**, Jan.–Feb., 15–17) To compensate for loss of heat from furnace to cooling and to prevent contact with the air and consequent oxidation and decarburization, the protective box method can be used. The parts are placed in a box of 18–8 stainless steel which has a device by which it can be inserted into and withdrawn from the furnace. The parts can then be transferred for immersion with minimum contact with the air.

Malconization—process for hardening stainless steels (*Acciaio-Inossid*, 1959, **26**, (4), 164–165; from *Macchine*, 1958, **13**, Dec., 1197–1199) The Chapman Valve Manufacturing Co. has perfected an original method for surface hardening stainless steel by additions of hydrogen on to the surface to be treated. The advantages of this technique are good corrosion resistance, core tenacity, extra-hard surface, and minimum effect on dimensions.

On the deformation of induction hardened steels S. Ishida and Y. Sakai (*Trattamenti Term.*, 1959, **2**, Sept.–Oct., 14–19) A description is given of experiments to measure dimensional changes occurring as a result of induction hardening of various test-pieces of carbon and Cr–Mo steels. The conclusions are (1) that the external and internal dia. increase in the case of deep hardening but that there is a reduction when hardening is less deep. (2) Minimum deformation of external and internal dia. is obtained with a temper ratio of 1:8. (3) An increase in thickness occurs in each case. (4) Dia. increases, in the case of less deep tempering, take place when preheating is carried out.

Decarburization and denitriding of iron–silicon alloys J. D. Fast and H. A. C. M. Bruning (*NV Philips Separaat* 2794; *Z. Elektrochemie*, 1959, **63**, (7), 765–772; reprint) Fe–Si alloys with up to 3 wt-%Si were heated for 2 h in pure and in wet H_2 at 900°C. Denitriding takes place in dry H_2 but is greatly retarded even by traces of water vapour; rate of N removal is independent of water content of the H_2 in the absence of Si. C is not removed in dry H_2, but decarburization takes place in presence of water, and rate of C removal increases with the amount of water present. The mechanism of the reactions is discussed.

Annealing the casting directly in the mould Ya. I. Mel'man and V. P. Filip'ev (*Lit. Proizv.*, 1960, (1), 40) The casting of a large component for an assembly crane is described, and after risers and sprues have been cut away, the casting still in the mould was heated by a gas flame to 860° for 1·5 h. UTS was found to be 60·7 kg/mm², yield-point 32·7 kg/mm²; elongation 19·5%, and reduction of area 31·2%. Chemical composition: 0·38%C; 0·85%Mn; 0·32%Si; 0·03%S; 0·035%P. No warping was observed.

Comparison of the cooling power of liquids used for quenching Guillemeau (*Centre Doc. Sidér.*, 1959, **16**, (8), 1809–1817) After a review of the liquids available for quenching and the factors which affect the cooling rate, apparatus designed to assess cooling power is discussed.

Sizing jig in quench cycle E. C. Buckingham (*Met. Prog.*, 1960, **77**, Feb., 129–130) A heating installation with an internal sizing tool is described, which is used to obtain accurately dimensioned parts of AISI 8630 steel, which is liable to non-uniform hardness and distortion during oil quenching.

The kinetics of the first stage of tempering M. Hillert (*Acta Met.*, 1959, **7**, Oct., 653–658) The first stage of tempering of martensite is considered as a normal diffusion process without using the dislocation-attraction model. The diffusion coefficient of carbon in martensite is derived theoretically and is shown to vary exponentially with the carbon content.

Reduced tempering of cold-rolled sheets of type 08 kp rimming steel G. F. Chub (*Stal'*, 1960, (8), 757) A note from Zaporozhstal'. Schedules are established.

FORGING, STAMPING, DRAWING AND PRESSING

Impact stress in hammer forging S. Omodaka (*Bull. JSME*, 1958, **1**, Nov., 348–356) Tests with model hammers and steam hammers giving various values of impact force and relative conditions necessary for theoretical design of mount and foundation are measured by wire strain gauge and Braun tube oscillograph. Through static calibration of the apparatus the absolute value of impact stress of the article hammered and the impact force of the hammer are obtained. Results are described.—S.H.-S.

Hydroforging—a new fabricating technique for tubing M. L. Samuels (*Met. Prog.*, 1960, **77**, Feb., 69–74) The coarse columnar structure of centrifugally cast tubes is broken up by hydraulic expansion from the inside, followed by annealing at 1950–2050°F. The process is in commercial production, in sizes from 8–18 in dia.

Explosive metal forming C. P. Williams (*AISI Reg. Techn. Meetings*, 1959, 333–350) The mechanism of high explosive forming is explained and possible applications for it are described and investigated, with a finding that makes it applicable principally to relatively low-volume production.

The tensile test as a means of assessing thin sheet for deep-drawing A. A. Arantes and J. A. Cintra (*Bol. ABM*, 1960, **16**, July, 457–471) The deformation processes that occur in deep-drawing are correlated with parameters which are obtained from true-stress-strain curves. The plastic range of the curve is given by $t = ka^n$, where t is the stress and a the elongation. The coefficient of resistance, k, and the index of deformation, n, are shown experimentally to define the deep-drawing characteristics of mild steel. Three steels were tested and it was found that n and k increased with improving quality whereas the ratio Fe/Fn (yield stress/maximum stress), which has also been proposed as a test for deep-drawing properties, did not vary uniformly.—P.S.

General consideration of blank holding in deep drawing of sheet metals M. Miyagawa (*Bull. JSME*, 1958, **1**, (1), 95–101) Systematic tests of the effect upon wrinkling behaviour by blank holding with (1) springs, (2) dead weight, (3) fluid pressure, and (4) fixed, with clearance larger than thickness of the blank between the die and the holding-down plate, are mathematically discussed.—S.H.-S.

Comparative experiments in drawing rolling and extruding of bars through a pair of cylindrical rollers N. H. Polakowski and L. B. Schmitt (*Trans. Met. Soc. AIME*, 1960, **218**, June, 409–416) Square bars of cold drawn copper, mild steel, and 2024 Al alloy were forced through an adjustable gap between two hardened rollers by pulling or pushing. Conditions comparable with drawing, rolling, and containerless extrusion could be created at will. Push or pull forces as well as roll separating forces were measured as well as forming efficiency and coefficients of friction. For slow-rate deformation the values of μ were between 0·09 and 0·14.

Calculation of the drawing forces in rod drawing through dies with a convex entry bell I. Mecseki (*Draht*, 1960, **11**, July, 335–338) A method for calculation of the drawing forces for rods is presented for the case where the entry bell is not a straight line but is convex, for instance a circular trace. Measurements carried out on copper and brass rods showed fair agreement.—T.G.

Strains and stresses during drawing. Part III R. Levi (*Ing. Mecc.*, 1960, **9**, June, 33–40) In this third part the problem of non-rotational drawing is examined with special reference to the importance of shearing stresses and angular deformations. The physical properties of the material which controls these phenomena and the general principles of the relation between the shapes of pieces and blanks and the success of the operation are explained. Finally deep-drawing with variable depth is briefly described.

Mechanical and thermo-mechanical strengthening of low alloy and low carbon steels I. D. Kuzema and A. V. Prokhorov (*Stal'*, 1960, (8), 745–750) Cold stretching to the extent of 1·0–1·5% may be used instead of heat treatment to raise the yield-point of these steels. It is suggested that the straightening operation gives the opportunity for strengthening the steel by this means. An editorial note suggests that further work is required.

Patenting and pickling in the continuous process H. Klimm (*Neue Hütte*, 1960, **5**, June, 332–337) Possibilities of increasing production in East German wire mills are discussed. These include combining separate processes into a single continuous process, and welding the coil ends together, as a temporary measure until larger coil weights are available.

History and importance of steel-wire industry in India R. N. Dutt (*Iron Steel Rev.*, 1960, **3**, May, 25–30) A general review of types and uses of steel wire and production methods.

Continuous production of cast iron microwire in glass-insulation V. G. Timofeev (*Lit. Proizv.*, 1960, (1), 10–12) A method is described consisting of one operation for producing a 2–10 μ dia. wire in a glass insulation on a special semi-automatic apparatus, a description of which is given.

On wire drawing. The fundamental problem E. Ravelli (*Ing. Mecc.*, 1960, **9**, June, 7–13) While taking into account the assumed distribution of tensions in the metal in the plastic state the tractive force required for conversion from the initial plane section to the final plane section is calculated in the conventional way and in the absence of friction. An analytical demonstration is given of the radial stresses and normal pressures at the drawing die wall. From this the flow of the metal through truncated cone-shaped elementary layers co-axial to the wire axis may be deduced.

Draw holes made from Yakutsk diamonds for the drawing of microwire G. P. Gvozdyk (*Stal'*, 1960, (7), 658–659) Working losses are said to be lower than with imported stones. The life is also said to be longer by 3·3% in drawing 0·03 mm Kh20N80 wire.

Steel and speciality alloy extrusions. Part II (*Prec. Met. Mold.*, 1960, **18**, June, 43–44) This article consists of charts which give the chemical analyses and mechanical properties of most of the most commonly extruded ferrous metals. The extrusion process, it is claimed, will produce parts at the lowest possible costs. The severe mechanical working during extrusion fully refines the billet grain structure and results in the best mechanical properties.

The cold extrusion of steel H. Fischer (*Sheet & Strip Metal Users' Techn. Assoc. Annual Proc.*, 1951–52, **5**, 115–131) The theory of extrusion is briefly discussed, followed by sections on the design and operation of presses, and the construction and life of tools. **The cold extrusion of steel and the use of hydraulic presses** E. V. Crane (132–143) The technique of extrusion is explained and illustrated. **Mechanical press equipment for the cold extrusion of steel** E. K. Johansen (144–146, 151) The author discusses the factors involved in cold press work. **The relative merits of presses for the cold extrusion of steel** T. F. Massey (147–151) The nature of extrusion is discussed, and the requirements for presses and the types of press available, are considered. **Die steels for cold extrusion** E. Johnson and E. Bishop (159–170) The authors discuss the various types of die steel available, giving 16 typical analyses, under the headings: quality, heat treatment, hardness and hardenability, resistance to tempering, toughness, abrasion resistance, and ease of machining and handling. **Metallurgical requirements of steels for cold extrusion** D. V. Wilson (187–200) The influence of composition, microstructure, reduction, surface quality of blanks, rates of straining and of strain ageing on the behaviour of steel during cold extrusion and the properties of the resulting extrusions are discussed.

Extrusion of metals: Theory and elements of calculation. Part III S. De Filippi (*Ing. Mecc.*, 1960, **9**, June, 47–58) This third part describes Hencky's theoretical method giving the necessary simplifications. Because of calculation difficulties Prager's graphical method is outlined, with two numerical examples. The results obtained from the various theories set out in the two previous articles and the present article are compared and finally the influence of operating temp. and velocity on extrusion pressure is examined. **Part IV** (July, 41–45) This final article in the series describes practical examples of extrusion: various types of presses, their characteristics, and metallurgical aspects of the structure of extruded metal parts and their defects. It concludes by summarizing the advantages of the process.

ROLLING MILL PRACTICE

The system of ingot stresses and deformation during rolling in a blooming mill and the bite of the work rolls on the stock S. V. Makaev (*Stal'*, 1960, (7), 628–634) The difference in the limiting angles of bite during entry and after rolling are referred to the system of stresses and deformations in the metal and not to changes in the coefficient of friction.

Study of rolling force and deformation on a 4-high mill C. Roger and R. Quonten (*Centre Doc. Sidér.*, 1959, **16**, (11), 2427–2436) Strain gauges have been used to determine the deformation of the mill frame during rolling. From the deformation curve obtained it is possible to calculate the thickness of sheet rolled with an accuracy of $\pm 0{\cdot}15$ mm.—A.G.

Applications of roll ragging H. E. Muller (*Iron Steel Eng.*, 1960, **37**, May, 107–118) The theory of rolling with reference to the need for ragging is outlined, and various types of ragging and their geometry are discussed. Reference is made to defects arising from knurling.

The forces in roller bearings of stands in continuous wire mills H. Münnich (*Stahl Eisen*, 1960, **80**, Aug. 18, 1136–1147) In the last few years, four-row cylinder roller bearings have been used in the construction of continuous mills for wire and thin sections. Whereas the heavily strained bearings in the first stands showed a long service life the bearings in the last stands, which are very much less strained than the first, wore out in a much shorter time. Measurement showed that this was due to a tilting of the roll in the bearing and the resulting uneven loading of the bearing. The report is followed by a long and interesting discussion.

The rolling of 750-kg ingots of free-cutting steel R 10 N. U. Akaev (*Stal'*, 1960, (8), 731–732) Difficulties encountered in the production of large forging ingots are described. A casting and rolling technique for large ingots was developed and is set out.

The development of lightened sections at the Magnitogorsk integrated steelworks N. I. Sirazitdinov (*Stal'*, 1960, (7), 624–628) The new sections are indicated with comparisons of their strength and weight with those of the older sections. Rolling conditions are reviewed, the thinner section gives a larger temp. drop and hence a fall in ductility and an increase in the power required. Nevertheless a longer total output of section is secured and metal saved also makes up for the power consumed.

Properties of lightened double-flange beams and channel sections and special features of their production P. A. Aleksandrov, I. V. Gunin and I. N. Filippov (*Stal'*, 1960, (7), 619–623) Newly developed sections have given great economies in metal and increased output. Originally, however, output fell, roll life was reduced, and many rejects were encountered. How these difficulties were overcome is described, especially the new roll pass design. Heavy beams should be cooled in the upright position to reduce residual stresses.

Application of standard numbers to the standardisation of metallurgical products F. Fabriani (*Bol. ABM*, 1960, **16**, July, 487–496) The author shows that standard numbers can lead to a single system of standard sizing of metallurgical products and that a change to this system can proceed smoothly. Simplicity and economy would result.—P.S.

The choice of a practical type of sheet rolling mill B. S. Shapiro (*Stal'*, 1960, (8), 722–726) Experience at various mills is assessed and various opinions expressed in the literature are considered. For most purposes the mills now in operation are quite satisfactory. For bi-phase austenitic–ferritic and ferritic–austenitic stainless steels an additional roller hearth furnace between the reversing and continuous stands is required. Other recommendations are made.

Study of rolling undertaken under the auspices of the E.C.S.C. Summary of principal results J. Stremsdoerfer (*Centre Doc. Sidér.*, 1960, **17**, (4), 977–986) Mention is made of experiments carried out to obtain more information regarding the differing characteristics of extra-mild, non-annealed rimming steel depending on the process it has to undergo. These showed that the upper elastic limit of sheet hot rolled on a continuous mill can vary between 33 and 25 kg/mm² whereas after normalization, the upper limit is at 20–24 kg/mm². The ECSC project aimed at studying rolling factors which could affect the mechanical characteristics of these steels. The present study describes the trial programme and the main findings. The trials showed that the appearance of large grains was due to temp. factors at the end of rolling and confirmed that for extra mild steels only differing in carbon content, those with the higher content had higher elastic limits, which seems paradoxical unless the carbon content of the ferrite only is taken into account.

Controlled rolling P. Blain (*Centre Doc. Sidér.*, 1959, **16**, (8), 1787–1794) Controlled rolling involves the regulation of the whole cycle of successive deformations and temp. taking account of the time elapsing between passes. Factors involved are discussed with particular reference to the effect on grain size of the product.—A.G.

The causes of gauge variations in hot strip mills and their correction R. B. Sims (*Iron Steel Eng.*, 1960, **37**, May, 69–83) The causes of gauge variations are analysed, and are shown to be mainly due to differential between the finishing speed of the last roughing stand and the entry speed of the first finisher, together with variations in applied strip tension. It is shown how optimum results can be obtained with automatic gauge control, operating with raised looper rollers and constant interstand tension.

On the equipment of No.2 continuous wire rod mill at Kokura steel works M. Nose, Y. Yoshiyagawa, and T. Ogura (*Sumi. Met.*, 1960, **12**, Jan., 355–360) An illustrated review.

On a new wheel rolling mill H. Gunji and T. Kimura (*Sumi. Met.*, 1960, **12**, Jan., 361–367) An illustrated review.

Tool for marking the blanks at the ends L. M. Vitushinskii, N. K. Kleta, and A. B. Gorban' (*Stal'*, 1960, (8), 740) A device for stamping the ends of three blanks simultaneously is illustrated.

Nippon Kohan installs new cold forming line (*Iron Steel Eng.*, 1960, **37**, May, 155–156) The cold roll forming mill for highway guard rail, supplied by Kane and Roach Inc., of Syracuse, NY, to Nippon Kohan is described and illustrated.

The change in mechanical properties of steel during cold rolling N. A. Troshchenkov and L. A. Zagadchenko (*Stal'*, 1960, (8), 735–738) Tests on 11 types of steel are reported using a four-high reversing mill and with reductions of 5–15% per pass. The findings are shown as curves. Tensile strength does not rise proportional to reduction, increasing at the start and then falling. Anisotropy increases during rolling, especially with EI 811 steel. Hardness of ductile steels increases but steels hard before rolling are not greatly changed.

The relationship between tube scrap due to laps and laminations and the chemical composition of the steel N. K. Solomakha (*Stal'*, 1960, (8), 729–730) Statistical studies showed correlations of rejects with tube dia. and S and P contents. The smaller dia. of tubes revealed defects in the reduction process and usually made them more serious. The defects are due in the first place to excess S and P. It is estimated that reduction of these to 0·005% would decrease the incidence of defects by 7–10%.

A technique for measuring eccentricity in metal tubes B. E. Noltingk (*Instr. Practice*, 1960, **14**, July, 749–756) An electrical induction gauge capable of giving the eccentricity of the whole output of seamless tubes is described.

Study of conveyors and coilers R. Saulnier (*Centre Doc. Sidér.*, 1960, **17**, (4), 963–975) This study which is limited to wire and bar mills aims at reporting on the various types of coilers and conveyors of coiled products and is based on replies by eight French works to a questionnaire. Ample layout diagrams of various systems are given and there is a note on the personnel required on plant of the standard type.

MACHINERY AND SERVICES FOR IRON AND STEELWORKS

The main girders of steelworks bridge cranes S. Bellone (*Ing. Met.*, 1960, **9**, July, 29–33) In view of the high cost and difficulty of maintaining means of lifting and transporting, and particularly electric bridge cranes in steelworks and foundries, special methods must be used in their design. Useful assistance is given in a manual of instructions produced by the Italian National Research Council which deals with bridge cranes and similar steelworks equipment but experience in the construction of such equipment for heavy and continuous use is essential.

Possibilities for ac cranes for steel mills H. A. Zollinger (*Iron Steel Eng.*, 1960, **37**, May, 119–122) Advantages of ac cranes include better crane life, lower maintenance, and power economies. Some design and performance data are given.

Dual capacity hoist for EOT cranes D. Schaper (*Iron Steel Eng.*, 1960, **37**, May, 130–132) The device described gives a single hoist crane the advantages of a dual hoist, using a re-reeving arrangement in the hoist mechanism.

Margam critical pressure boiler and power plant (*Eng. Boiler House Rev.*, 1960, **75**, Aug., 253–260) An illustrated account.

Electricity in steel-making T. B. Rolls (*J. Inst. Elect. Eng.*, 1960, **6**, Feb., 83–89) A review of an integrated works with notes on mill drives, power sources and supplies, distribution, lighting, and instrumentation.

Modern electric systems in the steel industry —new concepts in design and maintenance E. H. Browning (*AISI Reg. Tech. Meet.*, 1959, 19–51) A review of the initiation and development of new ideas, such as automatic programming, the use of in-line computers, with highly transistorized circuitry adjacent to the process, and data accumulation treatment and a description of their up-to-date application to blast-furnaces and the electrical systems used in steel mills today.

Auxiliary drive static rectifiers E. B. Fitzgerald and E. J. Posselt (*Iron Steel Eng.*, 1960, **37**, May, 140–143) A new standardized drive is

described which incorporates several features making it suitable for use with a number of heavy auxiliary drives. Packaged magnetic drives incorporating silicon diodes.

Liquified petroleum gases (*Brit. Steel*, 1960, **20**, Feb., 66–67) Possible applications of L.P.G. as a fuel for portable petrol and diesel engines are discussed with examples of steelworks plant.

The water economy of the La Chiers works and the measures taken to prevent river pollution D. Rabe (*Stahl Eisen*, 1960, **80**, Aug. 18, 1167–1168) The Hauts Fourneaux de la Chiers polluted the river Chiers heavily in former times and were forced to take measures to prevent this pollution. The water consumption is 9 500 m^3/h and there are two circuits, the open one and the closed one. By using recirculated water the water consumption from the river is reduced to 4 300 m^3/h. The measures for prevention of river pollution are mainly the precipitation of dust from the sintering plant and from the flue gas cleaning.—T.G.

WELDING AND FLAME-CUTTING

Modern arc welding of cast iron J. Babnik (*Varilna Tech.*, 1958, **7**, (3–4), 54–57) Cast iron welding techniques are still being improved. Gas and electric welding still raises very difficult problems, particularly in the repair of cast iron structures in railway workshops. The author briefly describes hot and semi-hot welding and concludes with practical instructions for the cold welding of the cast iron.

Welding low-carbon martensite W. P. Hatch, R. E. Travis, and C. E. Hartbower (*Weld. J.*, 1960, **39**, April, 141s–146s) This is a description of work carried out to investigate low-carbon steels in welded structures. The results suggest that the strength and toughness of welded joints from this steel are outstanding.

Spot welding of carbon steel I. W. Johnson (*Weld. J.*, 1960, **39**, March, 89s–96s) This is an interpretive report on the spot welding of carbon steel, summarizing all the available information and data on the subject. The metallurgy, mechanical properties, design and testing of welds, and appropriate electrodes, are considered (17 refs).

Metallurgical problems in the welding of steels of various types J. Björkroth (*Acciaio Inossid.*, 1959, **26**, (4), 140–156) This article discusses the general problems involved and then deals in more detail with the welding of low alloy steels, chrome martensite steels, plated steels. The successful welding of an Avesta 832 SKT steel plate of 35 mm thickness on to an ordinary steel plate is described.

Comments on the welding of various types of steels (*Acciaio Inossid.*, 1960, **26**, (5), 222–224) This article summarizes some fundamental ideas regarding the phenomena which take place during the welding of two different types of steel.

Building up of tool steels in argon shielded atmospheres (carried out on turning tools), with special reference to cost saving V. Prosenc and P. Stular (*Varilna Tech.*, 1959, **8**, (2), 26–31) Comparative tests of welding processes show that building up in the argon shielded atmosphere is very suitable for the production of new tools and also the repair of worn tools both from the technical and economic points of view. Tests were carried out on Jugoslav high-speed steels BRC, BRW, and BRW 2. Comparative calculations based on the Jugoslav prices have shown that the costs of production of a built-up turning tool were from 30 to 50% lower than those for tools made entirely from high-speed steel.

Repair by CO_2 welding V. Gilde (*Varilna Techn. Report on Welding Conference*, 1959, 118–120) [In English] A description is given of CO_2 welding equipment used for semi-automatic operation. Filler materials used and their composition are given. The economies of this process in comparison with manual welding have been shown by an experiment. Working productivity increased by about 300%.

Repairing by partial electroslag welding of heavy sections V. Anders (*Varilna Techn., Welding Conference*, 1959, 111–116) [In English] Repair welding of heavy cast steel cross-sections is very difficult using conventional methods. By partial electro-slag welding the task can be successfully performed under normal operating conditions. Welding data can be predetermined and observed with accuracy by subdividing the cross-section to be welded into smaller individual sections of equal shape and size. Compared with methods used hitherto, electroslag welding results in considerably reduced repair time and non-warping performance.

Pressure gas welding of concrete-reinforcing steel B. Mejak and P. Stular (*Varilna Tehn.*, 1959, **8**, (1), 12–15) Due to the mechanical and metallurgical properties of joints, reinforcing steels welded by pressure gas welding can be compared with those obtained by flash welding under pressure. The article gives the results of research carried out and examples of applications of the process in Germany and at the Institute of Welding in Ljubljana.

Development of welding equipment in Jugoslavia L. Knez, F. Mihalinec, K. Špigl, Z. Smolcic, V. Diniç, S. Ferušic, and P. Stular (*Varilna Tehn., Welding Conference*, 1959, 37–52) [In French] The article begins with a description of the development of welding techniques at the Jesenice Steelworks and at the Elektroda factory at Zagreb. The production of welding electrodes, power transformers, new industrial X-ray apparatus, and equipment for defectoscopy is dealt with. Finally, present welding equipment and plant is reviewed.

Welding practice in the Jugoslav machine tool industry S. Vukicevic, V. Kabaj, M. Einhauer, A. Martini, C. Jovanovic, and P. Cerjak (*Varilna Tehn., Welding Conference*, 1959, 76–79) [In English] The writers describe the development of welding techniques in the Jugoslav machine tool industry giving numerous illustrations of completed welded structures.

Jugoslav shipbuilding and welding J. Rožanic and S. Iliassich (*Varilna Tehn., Welding Conference*, 1959, 60–64) [In English] The article gives a general review of the shipbuilding industry and recounts its reconstruction and modernization since 1945 in the light of welded techniques, the problem of training skilled workmen, and the practical application of methods of welding control.

Electro-slag welding G. Foti (*Riv. Ital. Saldatura*, 1960, **12**, May–June, 113–120) The writer describes the electroslag welding process developed by the Paton Institute with special reference to the welding parameters, the filler materials and the fluxes. The metallurgical principles of the process and welding defects are also discussed. Finally the operation of the equipment used for electroslag welding is described and details of two types are given.

Application of electro-slag welding A. M. Horsfield (*Brit. Weld. J.*, 1960, **7**, May, 337–341) The author describes cleetro-slag welding, mentions its advantages, and compares it with other methods. The quality of the welds obtained, and the various appliations are also discussed.

How electroslag welding is used in Russia A. B. Tesmen (*Met. Prog.*, 1960, **77**, Feb., 118–122) An outline of the method, with a report of its applications in USSR to the welding of thick sections.

Friction welding J. Mandaus and J. Vobořil (*Czech. Heavy Ind.*, 1960, (8), 3–10) [In English] A review with descriptions of the process, the origin of heating, the machines used, and the advantages where it can be employed.

Electron beam welding M. E. Harper and E. G. Nunn (*Brit. Weld. J.*, 1960, **7**, May, 331–336) The advantages of this type of welding, carried out *in vacuo*, are stressed, and the principles, equipment, and applications of the process are discussed.

Semi-automatic welding with fine wires R. V. Brimble, J. A. Lucey, and D. B. Tait (*Brit. Weld. J.*, 1960, **7**, May, 342–352) The advances made in welding of steel by the gas-shielded metal arc process, due to the development of feed equipment for small dia. fine wire, and improved power sources, are described, and the uses of this new equipment are indicated.

The alumino-thermic welding of rails F. Moneva (*Inst. Hierro Acero*, 1960, **13**, April–June, 617–624) After pointing out the advantages of welded track the author gives details of the alumino-thermal (thermite) technique of welding lines and describes examples from Spain and abroad of welded track lengths in use.—P.S.

Approach to electroslag welding in the United States (*Met. Prog.*, 1960, **77**, Feb., 123–125) The principle of the method and the operating conditions are outlined.

Influence of weld details on fatigue of welded beams and girders W. H. Manse and J. E. Stallmeyer (*Brit. Weld. J.*, 1960, **7**, March, 188–200) A discussion of the effect of stiffeners, splices, etc., which might be expected to reduce fatigue strength.

Fabrication, erection, welding and testing of largest welded T-1 steel spiral casings E. L. Seeland (*Weld. J.*, 1960, **39**, April, 307–313) A detailed description of the manufacture of these hydroelectric turbine spiral casings, and of the considerations taken into account at the design stage, is given.

Inert gas arc welding in relation to the weldability of certain metals and alloys P. Štular (*Varilna Tehn.*, 1959, **8**, (1), 3–12) The article describes the main characteristics of the weldability and welding of Al and its alloys as well as 18–8 stainless steels by the TIG and MIG processes.

Importance of accessory equipment on the productivity rate for welded metal construction (*Tecn. Indust.*, 1960, **38**, June, 888–874) It is pointed out that positioning and assembly jigs have an important role in welded construction production and various illustrations of such jigs are described. A suitable administrative organization for a welding firm is also discussed: there should be offices for study and design, work methods, and work planning.

Control of welding distortion E. H. Lee (*Metro.-Vick. Gazz.*, 1959, **30**, June, 148–155) From *Weld. Met. Fabr.*, 1959, March.

Notch-ductile weld metal for dynamically loaded T-1 steel structures J. S. Kobler (*Weld. J.*, 1960, **39**, April, 160s–171s) An investigation was carried out, resulting in the development of electrodes suitable for producing weld deposits that react favourably to a stress-relief anneal, and show static and impact properties very similar to those of the T-1 base metal.

Fundamental correlations concerning the transfer of alloying elements from electrode into weld in the arc welding and facing of steel A. A. Erokhin (*Svaroch. Proizv.*, 1956, (4), 4–12) Losses of elements by oxidation and spattering and other processes are evaluated and processes and rates of transfer of the remaining alloying constituents are discussed in relation to concentration in the electrode and to oxidation potential.

Relationship between microstructure and mechanical properties of mild steel weld deposits K. J. Irvine and F. B. Pickering (*Brit. Weld. J.*, 1960, **7**, May, 353–364) The results of optical and electron-microscope studies of metal-arc, argonarc, atomic hydrogen, and oxy-acetylene welds in mild steel are given.

Kinetics of austenite decomposition in steels during welding N. N. Prokhorov, E. L. Makarov, and V. I. Gospodarevskii (*Metallov. Term. Obra. Met.*, 1959, (3), 13–16) The decomposition of austenite during welding was studied magnetometrically. It is claimed that the changes of structure are revealed more accurately than by dilatometric work, in the temp. range studied. The apparatus used is described, and the results obtained are given (in particular, the correlation of austenite transformation temperature with resistance to cold cracking).

Droplet transfer during arc welding in various shielding gases L. F. Defize and P. C. van der Willigen (*Brit. Weld. J.*, 1960, **7**, May, 297–305) The nature of droplet transfer is discussed and work on the size of the droplets under various conditions in CO_2 and argon is described. High-speed cinematography was used in the work.

Influence of hydrogen on welds J. Zvokelj (*Varilna Tech.*, 1959, **8**, (4), 92–95) This article reviews current works dealing with the hydrogen content of welds. The article describes the conditions for the development of H_2 in welds and then discusses the three most important weld defects caused by H_2 namely—fish-eyes, under-bead cracks, and microcracks.

Development of hydrogen content and mechanical properties of arc welds with coated electrodes as a function of time (*Varilna Tech.*, 1958, **7**, (3–4), 68–71) The aim of the tests, described is to measure the rate of reduction of H_2 content as a function of time in the deposited metal by various types of electrodes. Simple tensile tests were used. Hydrogen dissolved in the metal is reduced as a function of time after welding until its content reaches a minimum value.

Constitution diagram for stainless steel weld metal A. L. Schaeffler. **Revised section of Schaeffler constitution diagram** W. T. Delong (*Met. Prog.*, 1960, **77**, Feb., 100B) A reproduction and discussion of these diagrams (98–100).

A study of cracking in low-alloy steel welded joints J. T. Berry and R. C. Allan (*Weld. J.*, 1960, **39**, March, 105s–116s) The authors present a review of the literature on 'cold cracking', and then describe some preliminary results of an investigation into the phenomenon. These results, and those of earlier workers are used in the formulation of a theory of 'cold-cracking' (92 refs).

A survey of brazing (*Varilna Tech.*, 1958, **7**, (3–4), 61–65) The article defines brazing and compares brazing with fusion welding. Also dealt with are determination of the operating temp., description of operating practice, shape of the brazing joint, surface preparation of the base metal, flame-hard brazing, and preparation of metal.

Brazing in controlled atmosphere furnaces G. Kluge (*Trattamenti Term.*, 1959, **2**, Nov.–Dec., 15–22) This article describes flame brazing in a controlled atmosphere and the furnace characteristics required. He gives the advantages of flame brazing as (1) substantial saving in labour, space, time, and material costs; (2) mass production of complicated parts which previously required the use of specially skilled men; (3) increase in production as more brazing can be carried out at the same time; (4) reduction in the number of rejects owing to the high quality of the product; (5) elimination of deoxidizers, making reprocessing unnecessary.

High-temperature brazing experiments R. R. Ruppender (*Met. Prog.*, 1960, **77**, Feb., 95–97) The use of statistical analysis in assessing the results of fusion welding experiments is discussed.

Designing brazed joints for 1 000°F and above J. C. Reeves (*Prod. Eng.*, 1960, **31**, Aug. 1, 40–43, 45) A review of the brazing of stainless steels, alloy steels, and superalloys. Choice of brazing alloy is discussed and tables of joint strengths are shown.

Development of oxidation and liquid-sodium-resistant brazing alloys D. Canonico and H. Schwarzbart (*Weld. J.*, 1960, **39**, March, 122s–128s) Fe, Cr, and Ni-based filler metals were investigated, and considerable success was achieved by the use of Ni–Cr–Ge and Li-containing alloys.

Oxidation-resistant brazing alloys G. H. Sistare jun. and A. S. McDonald (*WADC TR-55-52, PB* 130403, 1955, April, pp.45; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 91; no abstract).

Advantages of propane cutting and its use in welding in Jugoslav conditions P. Stular (*Varilna Tech.*, 1959, **8**, (2), 38–41) The author gives the advantages of propane cutting—large reserves in Jugoslavia, low costs, excellent for the autogenic cutting of steels, and outlines certain welding methods proved by tests carried out in various countries as well as at the Institute of Welding in Ljubljana. On the basis of these findings the use of propane in cutting is recommended.

Practical results of comparative tests of propane and acetylene cutting in 'Metalna' (Jugoslavia) P. Cerjak (*Varilna Tech.*, 1959, **8**, (2), 41–44) The writer proposes that C_3H_8 cutting of metals should be introduced in 'Metalna', basing this on the results of a comparison of tests of propane cutting of structural material with oxy-acetylene cutting. He recommends that propane cutting should be used in large industrial plants.

Analytical study of natural gas–oxygen cutting, theory and application J. C. Worthington (*Weld. J.*, 1960, **39**, March, 229–235) The theory of the reactions involved in, and the effect of variables such as torch and tip design on this type of cutting are discussed. Methods of cutting mild steel and non-magnetic steel are described, as is bevelling. It is concluded that natural gas is, at present, the most economical fuel for the oxygen cutting of steel.

Profiling of sprocket segments with the electronic oxygen-cutting machine National Cylinder Gas, Chemetron Corp. (*Weld. J.*, 1960, **39**, April, 351–353) The improvements made in the Pershing Road Plant of Link–Belt Co., Chicago, by changing to electronic line tracing (from automatic oxygen cutting) are described and explained. The gain in accuracy is stressed.

Tungsten-arc cutting of stainless steel G. A. Conner (*Weld. J.*, 1960, **39**, March, 215–222) The advantages of this method of cutting of the 300 series of stainless steels are explained. In particular, cutting and bevelling by this means provides a better fit for nuclear-applications welds, and thus leads to higher weld quality, and reduced costs.

Microstructure and the strength of the joints in the pressure welding of multi-layer steel E. I. Astrov (*Svar. Proizv.*, 1960, (2), 21–24) The effect of the microstructure of the adjoining zone of the strength of the weld joints of carbon and alloy steels of different chemical compositions has been investigated. It has been shown that strong joints can be obtained without visible layers because of heterodiffusion; or with sharp boundaries. The latter type of joint is normally produced when welding together high-alloy steels or with low carbon steels. In either case, no oxides, non-metallic inclusions, or coarse phases should be present in the welding zone. The nature of the microstructure of the adjoining zone determines the strength of the weld joint.

Investigating the properties of the metal welded on by a few heat-resistant electrodes F. I. Pashukanis and A. E. Runov (*Svar. Proizv.*, 1960, (2), 5–9) The heat treatment of austenitic–ferritic deposited metals of the type 1Kh19N12M2F, 1Kh19N12M2K3VF, and 1Kh19N10B between 1 050 and 1 200° dissolves only a limited amount (up to 4–5%) of the ferrite phase. To increase the plastic properties of such deposited metals doing extended periods of service at the sigma-phase formation temp., it is advisable to see that in its initial structure the metal does not contain more than 4–5% of ferritic phase and to carry out the austenitization of the welded joints at between 1 050 and 1 200°.

Long term strength of the welding joints of low carbon steels L. G. Achkasov (*Svar. Proizv.*, 1960, (1), 19–23) Tests for long term strength of welded specimens of St3T low-carbon steel have shown that electric arc welding of this steel with OMM–5 electrodes gives a joint the long term strength of which between 325 and 525° is not lower than that of the base metal. The nature of the failures of the specimens in the weld metal and in the base metal depends on the temp. of the test. At 325° all specimens showed intercrystalline failure. At 425, 475, and 525° failure along grain boundaries was observed even after only 260, 170, and 70 h respectively.

A method for the quantitative assessment of the tendency of welding joints to developing cold cracks B. A. Kolodnaya (*Svar. Proizv.*, 1960, (2), 12–15) Cross-shaped specimens welded during the tests were used. The specimens must be given the stress conditions of the 1st order corresponding to the conditions of the welding operation. They must reproduce the different conditions of saturation with and elimination of H_2 during welding, also the thermal cycle should correspond to the welding process. The specimens were examined after every method of welding for the presence of cracks and set against the respective electrode. The findings are tabulated.

Microstructural causes of heat-affected zone cracking in heavy section 18–12–Nb austenitic stainless-steel welded joints N. E. Moore and J. A. Griffiths (*JISI*, 1961, **197**, Jan., 29–30) [This issue].

The effect of residual stresses on the resistance to vibration of specimens with transverse welding joints D. I. Navrotskii and V. N. Savel'ev (*Svar. Proizv.*, 1960, (5), 15–17) Investigations have shown that in the most typical joints (butt welds and angular seams) the action of transverse residual stresses is fully cancelled out by the effect of work-hardening of the welding zone. The anneal usually carried out to remove welding stresses, which at the same time removes the hardening stresses, is therefore not advisable.

Some patterns of carbon diffusion in the weld joints of pearlitic steels L. S. Livshits and S. I. Panich (*Svar. Proizv.*, 1960, (5), 23–24) The migration of carbon in the welding zone between the different types of metals (weld metal and steel) has been investigated. The experiments here related show that at 500–700° carbon diffuses in the joint through the α-solution. In the sections of the joint containing elements forming stable carbides, the carbon concentration in ferrite is much lower than in the sections which contain less powerful carbide forming elements. It has also been shown that the depth of the decarburizing zone for the different alloys depends on the duration and temp. of the operation. At 550° decarburization proceeds very slowly, at 650°, its rate is perceptible and cannot be neglected, at 700° the rate is excessive and may cause premature failure of the weldment.

Non-mechanical jointing of metals G. Fitzgerald-Lee (*Eng. Mat. Design*, 1960, **3**, May, 291–297) Soldering, brazing, and welding are surveyed. There is not much reference to ferrous metals.

Cementing metals together G. Shvarts (*Svar. Proizv.*, 1960, (2), 39–42) Since 1955 this method has been widely used in East Germany for obtaining permanent joints. The disadvantages of rivetting are eliminated, for example, the cross-section is not reduced, no stress peaks are formed but an even distribution of the loads is achieved with no distortion, etc. Materials of different types can be cemented together. Various substances for cementing are mentioned: 'Ebonite', a product made on the base of plasticizer 32, which in turn is obtained by polymerization of butadiene at a pressure of about 3-5 atm. by using metallic sodium and 1% diphenylamine as stabilizer. Figure 32 at the beginning indicates a molecular weight of 32000. Many more substances are reviewed.

New equipment for gas flame treatment of structural metals made by VNIIAvtogen (*Svar. Proizv.*, 1960, (5), 40–42) A few new types of machines are described for oxygen cutting, gas cutting, and for automatic gas soldering, and some technical specifications are given.

Experience with the type A8P–1 gas cutting machine A. V. Krupenya (*Svar. Proizv.*, 1960, (2), 38) Specifications are given of a reconstructed machine which allows cutting of 4 mm thick steel at a rate of 900 mm/min.

Electro-oxygen cutting of metal N. F. Varfolomeev (*Svar. Proizv.*, 1960, (1), 35) A new method of electro-oxygen metal cutting is proposed by the author from the Kiev National Institute of the Air Force. It is based on the experimentally demonstrated fact that induction heating of the metal by h.f. currents may be used with advantage instead of the gas or oxygen-gas flame, and the method is specially suitable for machines cutting with gas, which can be easily adapted.

MACHINING AND MACHINABILITY

New processes for machining metals W. Ghetu (*Met. si Constr. Masini*, 1960, (1), 18–23) Very general considerations for adapting existing automatic machine tools to rapid control systems are reviewed. A few examples are given of operations with magnetic tape and computer control.

Cutting force and speed of cutting for machining stainless steels N. P. Golubov (*Stanki Instr.*, 1960, (3), 24) The machinability of 1Kh18N9T and 1Kh13 stainless and of EI 654 heat-resistant steels has been investigated with cutting tools of VK8 and T5K10 hard alloys without the use of lubricating-cooling liquids. Formulae are given for calculating the main parameters.

The temperature of the surface layer during the machining of the steel component V. A. Zhilin (*Stanki Inst.*, 1960, (2), 40–41) An increase in speed, of rate of feed, and of depth of cutting increases the temp. of the surface layer of the piece in work. The speed exerts the

greatest influence on temp. and the depth of the cut the least. The material contributes also to an increase of temp. as do the cutting tools.

Welding-on edges of high-speed steels to cutting tools N. I. Tashlitskii (*Stanki Instr.*, 1960, (4), 33–34) The direction and the magnitude of the cutting force is at the basis of the calculation for the required parameters. The theoretical method of calculating these is given. A method of electric arc welding is explained which has some advantages over the existing procedures.

Forming cutters for machining turbine blades of resistant steel A. A. Klimakhim (*Stanki Instr.*, 1956, **27**, (12), 23–25) Determining the optimum design of cutters of austenite steel, as used at the Leningrad Metal Works is described.

New type of steel for circular cutting dies A. G. Klyueva, B. L. Aleksandrovich, and G. G. Korolev (*Stanki Instr.*, 1960, (3), 24–26) The article reports on tests with 95KhG8V steel, and sets out the findings for optimum heat treatment, hardness, and heat-resistance after tempering at optimum temp. The values obtained demonstrate its suitability so that it may be used, as well as the older types 9KhS and EI 88.

Fundamentals of cutting tool lubrication R. H. Norris and E. J. Lownes (*Sci. Lubr.*, 1959, **11**, Nov., 26–35) After discussing the phenomena involved in the cutting and grinding of metals, cutting fluid characteristics and the selection of cutting fluids for various purposes is described. The laboratory evaluation of cutting fluids and radioactive tool wear methods are also dealt with.—T.G.

The evolution of soluble and straight cutting oils H. W. Hutton (*Sci. Lubr.*, 1959, **11**, Nov., 57–58) A brief historical review of the chemistry of cutting fluids over the last 110 years.

Developments in high-speed machining R. N. Cook (*Engineering*, 1960, **190**, July 8, 63–64) An analysis of metal cutting speeds according to tool materials and cutting method. Three groups are distinguished, up to 1000 ft/min with WC, 1000–30000 ft/min with TiC and sintered oxides, and up to 360000 ft/min with static tools and explosive propulsion of the workpieces.

Behaviour of the chip in steel cutting K. Okushima and K. Minato (*Bull. JSME*, 1959, **2**, Feb., 58–64) The effects of cutting velocity, nose radius, and depth of cut, and the effect of feed, and an analysis of the angle of flowing-out of chip, with chip classification and a review of the effect of cutting conditions on the shape of the chip are discussed and evaluated.

On the behaviour of the chip in steel cutting. Part II. The case of the parallel type chip breaker K. Okushima, T. Hoshi, and T. Fujinawa (*Bull. JSME*, 1960, **3**, (10), 199–205) Effects of feed, cutting velocity, and size of the chip breaker on the radius of curvature of the cylindrical helical chip are described and the reasons for effective chip breaking formulated in some equations on the basis of which a design chart is presented.—S.H.-S.

Investigation on the theories of orthogonal machining T. Ota, A. Shindo, and H. Fukuoka (*Bull. JSME*, 1959, **2**, Feb., 115–123) A mathematical review in which previous admittedly incorrect conclusions are corrected, and after preliminary discussion the generalized case of Lee and Shaffer's solution with built-up edge is investigated.—S.H.-S.

An analysis of the mechanism of orthogonal cutting K. Okushima and K. Hitomi (*Mem. Fac. Eng. Kyoto Univ.*, 1958, **20**, April, 95–116) [In English] A transitional flow region concept was used instead of the conventional shear plane. The findings agreed with experiments on Pb and brass.

Sliding-block type cutting test apparatus K. Okushima (*Bull. JSME*, 1958, **1**, Nov., 338–342) The principles, construction, use of, and tests carried out by an orthogonal cutting test apparatus using a sliding block are described, and the results are considered.—S.H.-S.

Tool steels for press tools and shear blades in sheet metal fabrication R. S. Watts (*Sheet & Strip Metal Users' Techn. Assoc. Annual Proc.*, 1951–52, **5**, 58–94) The properties and selection of tool steels (for sheet and strip deformation) are discussed, and then the heat treatment of these steels is considered in detail.

The deformation process in metal cutting W. J. McDonald and B. F. Murphey (*Trans. ASME, J. Eng. Ind.*, 1960, **82B**, Aug., 253–258) The analysis is carried out for a strain-hardening material taking into account temp. increase and flank rubbing. The strain imparted to the chip is a measure of the deviation from Merchant's original equation if the temp. rise is not so great as to make a great change in the stress-strain curve.

The manufacture of high-speed cutting tools for automotive and allied industries G. C. Lovitt (*IAAEJ*, 1960, **20**, June, 76–81, 87) Co-operation between toolmaker and user, selection of steels, heat-treatment, shaping, checking, surface treatments, and manufacturing procedure are discussed.

New methods of metal cutting to get fine surface at low speed (sub-zero-, reversal finish-, and ultrasonic-cutting M. Masuko and J. Kumabe (*Bull. JSME*, 1959, **2**, (7), 487–494) Three processes, which, at low cutting velocity, give excellent finished surfaces and smaller depth and magnitude of work hardening are discussed, the effects of these methods are reviewed, and a case is made out for their worth as against current trends for higher cutting speeds.—S.H.-S.

On ceramic cutting tools (in machining carbon steel K. Okushima and Y. Fujii (*Bull. JSME*, 1959, **2**, May, 217–223) The physical properties and life of ceramic cutting tools are examined and compared with those of carbide tools. Cutting performance of ceramics was affected by specific gravity, transverse rupture strength, and crystal structure, and failures of tools tested were found to be essentially similar in both classes, proper tool geometry and cutting condition being equally necessary in both cases for tool life.—S.H.-S.

The reclamation of cutting oils E. G. Ellis (*Sci. Lubr.*, 1959, **11**, Nov., 58–67) The machines and equipment for reclaiming oil from machining operations and swarf are described, some of these installations are reclaiming oil for 6*d.* a gallon that cost 4*s.* 6*d.* new. Filters installed in grinding and honing workshops are also described.—T.G.

Cutting fluid selection and special cases C. J. Taylor and B. V. Harris (*Sci. Lubr.*, 1959, **11**, Nov., 43–51) The factors to be considered in the selection of the best cutting fluid are discussed, and a number of actual applications quoted.—T.G.

Methods of cutting fluid application I. S. Morton (*Sci. Lubr.*, 1959, **11**, Nov., 39–43) Although the arrangements used for the application of cutting fluids are of long established types, there are possible alternatives of considerable technical interest which, when used, could lead to improved performance in the machine shop. The author deals with conventional practices, application of cutting fluid through clearance crevices, application as a mist and special methods of application for grinding (16 refs).—T.G.

Water-base cutting fluids I. S. Morton (*Sci. Lubr.*, 1959, **11**, Nov., 70–72) The term 'water-base cutting fluid' is used to denote any non-petroleum aqueous product used to facilitate machining operations. These fluids are sodium carbonate, trisodium phosphate or soap, and more recently sodium nitrite. Experience gained with water-base cutting fluids is briefly reported.—T.G.

Machinability study with a ceramic tool. IV. Performance of ceramic and carbide tools in cutting alloyed cast iron at ultra high speed K. Yamada, N. Nakayama, H. Kajihara, S. Sakai, and H. Mii (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1960, **9**, March, 107–113) The carbide tool wore out in a short time. The forces on the tool were smaller with cast iron than with steel, possibly because of the small deformability of the iron. The cutting speed was 670–1240 m/min.

Photoelastic determination of cutting tool stresses W. B. Rice, R. Salmon, and W. D. Syniuta (*Trans. Eng. Inst. Canada*, 1960, **4**, (1), 20–23) A periodic variation of stress pattern was observed confirming the periodic nature of the process. A photoelastic tool cutting lead was used.

Recent developments in machine tool coolants V. J. Haden (*Prodn. Eng.*, 1960, **39**, Sept., 529–536) A review on recent constituents of these liquids, with a note on reclamation.

Factors generating surface roughness in cutting A. Iwaki and M. Mori (*Bull. JSME*, 1958, **1**, (1), 86–95) Tests were made on brass, copper, mild steel, hard steel, and cast iron with surfaces mirror-polished. In cutting, the linear relation between the degree of generated roughness and the cutting depth, and the similarity between shapes of generated profiles according to property of material were considered. Abnormal roughness, generated by disturbance of built-up edge, was estimated with practical correlation coefficient, and auto-generated roughness, caused by non-uniformity of grain size and hardness of materials, was estimated with the auto-correlation coefficient.—S.H.-S.

Damping cutting vibrations H. Frommelt (*Machinery*, 1960, **97**, Aug. 24, 448–450) Results obtained with copper-infiltrated iron powder are given.

Effect of the relative displacement between the grinding wheel and the work upon the wheel depth of cut in the grinding operation S. Shiozaki (*Bull. JSME*, 1960, **3**, (10), 206–212) A review. At the conclusion it is stated that the grinding machine used was not a good one.—S.H.-S.

Applications of recommended point shapes for drilling cast iron (*PERA Bull.*, 1960, **13**, April, 87–89) The recommendations of a report are reproduced.

Technological machinings by electro-erosion. Part II G. B. Gamondi (*Ing. Mecc.*, 1960, **9**, June, 27–31) The conclusions drawn from a comparative sharpening test using WC-tipped tools which compared a wheel with an electro-erosion method, is that there is no marked difference between the two. The electro-erosion system is, however, more economical as a greater number of tools can be placed in the sharpening machine tank. In such a way extremely constant angles can be obtained for all the tools, while for tools with shaped cutting edges, specially shaped or extra-hard wheels are not required.

CLEANING AND PICKLING

Research on the adoption of a practical method of cleaning stainless steels in 800 and 1100 mm mills N. V. Keis and A. I. Komissarov (*Stal'*, 1960, (8), 740) A note from Chelyabinsk. Flame scarfing using Al–Mg powder has been adopted. It is only advisable to use it for sheets with surface defects.

Pickling inhibitors in galvanising A. Herz (*Mét. Const. Méc.*, 1960, **92**, June, 491–493) The difference between passivators (or neutralizers) and inhibitors (or attack limiters) is defined, and the theory of their action is discussed. The results to be obtained with various simple inhibitors are described and shown diagrammatically.—S.H.-S.

Efficient methods of pickling carbon steel in sulphuric acid solutions V. P. Barannik and T. D. Kolpakova (*Stal'*, 1960, (8), 753–754) Tests on the factors concerned in the process were made on 7 mm rods of type 80 steel. Pickling with 25–35% acid (rather higher than is customary) at 70–90° with additions of 3–9% common salt is recommended to improve scale removal and reduce metal losses.

Some aspects of pre-enamelling control and technique for sheet and cast iron A. K. Williams (*Inst. Vit. Enamel. Bull.*, 1960, **10**, Aug., 377–384) Faults in casting or pressing and design should be looked for.

Automatic control of the surface of steel strip V. A. Dolgalev, F. S. Astaf'ev, P. A. Tyukalov, and I. S. Mustyukov (*Stal'*, 1960, (8), 734–735) A cleaning train for tin plate is described using electrolytic degreasing in the central section of a set of brush rinsing, degreasing, and drying sections. The surface is scanned for stains, etc., and the causes and prevention of these are discussed.

Preparation of the metal surface. Comparison between simple degreasing and copper degreasing H. Richter (*Galvano*, 1960, **29**, Feb., 79–81) This article presents the case for copper degreasing. Experiments show that copper degreasing is more effective than simple degreasing. Adherence of subsequent coatings and brightness was improved.

Surface treatment of stainless steels G. Colombo (*Acciaio Inossid.*, 1960, **27,** (3), 429–432) The author in this first article of the series defines the process as surface polishing, mechanical finishing treatment, and non-mechanical finishing treatment. He then summarizes the various measures which must be taken to ensure maximum corrosion resistance. He describes the standard finishes which are mainly of a mechanical nature carried out on sheets, strip, tubes, and bars. He gives then the definition for standard AISI finishing for sheets, plates, strip, tubes, and other shapes. He concludes with a few remarks on choice of materials.

Influence of the nozzle shape and operating pressure on the efficiency of compressed air shot blasting units K. Adlassnig (*Giesserei*, 1960, **47,** April 21, 211–214) The influence of these factors on air consumption, nozzle wear, and blasting efficiency is examined.

PROTECTIVE COATINGS

Hot-dipped metallic coatings J. H. Nicholls (*Corros. Techn.*, 1960, **7,** April, 107–110, 117) The properties, preparation, and uses of Sn, Pb, Zn, and Al hot-dipped coatings are compared (13 refs).

Factors influencing the selection of metal finishes A. W. Wallbank (*Sheet & Strip Metal Users' Techn. Assoc., Annual Proc.*, 1951–52, **5,** 36–40) The purposes of metal finishes are discussed, the advantages of electrodeposition are considered, and physical effects, service, performance, appearance, and cost of the various finishes are compared.

On the thickness of protective coatings (*Peint. Pig. Vernis.*, 1960, **36,** Aug., 449–451) This article gives much useful advice on the thickness of various coatings to be applied to steel and discusses the extent to which effectiveness will depend on the use to which the steel is put or the atmospheric influences to which it is exposed.

How to determine requirements for rinse water in plating processes H. W. Parker (*Met. Prog.*, 1960, **77,** Feb., 82–83) An account of economies obtained in rinsing operations by reducing the water flow required.

Trends in the application of electrolytic chromium plating technique to an uncracked structure to improve corrosion resistance P. Morisset (*Chrome Dur.*, 1959–60, 75–82) The results of corrosion tests show that in the case of conventional 20 μ nickel plating of steel or zinc alloy the multiplication of the thickness of the Cr plating by 10 increases corrosion protection considerably more than by doubling the nickel plating (from 20 to 40 microns).

Use of wet sanding to improve the fatigue resistance of steel and light chrome alloy parts R. Brunetaud, R. Chevalier, and P. Lescop (*Chrome Dur*, 1959–60, 3–15) Electrolytic deposits of chrome result in a reduction of the fatigue limit. It was found by investigations that wet sanding at grade 90 of steel before Cr plating restores and in certain cases improves the fatigue limit to 10^8 cycles. Sanding conditions must be adapted to the basic metal—for high resistance steels it is necessary to increase sanding pressure.

Heat-treating electroless nickel coatings K. T. Ziehlke, W. S. Dritt, and C. H. Mahoney (*Met. Prog.*, 1960, **77,** Feb., 84–87) Effect of heat treatment on the structure and properties of coating containing 7–10·5%P is described. Maximum hardness is independent of P content and occurs during the formation of an interim lattice from the amorphous as-deposited structure.

Thickness measurements on platings by means of an electron probe R. Kriegler and B. W. Schumacher (*Plating*, 1960, **47,** April, 393–395) An electron beam of variable energy is directed into the sample; the energy at which the electrons penetrate the plating and reach the base metal is obtained by measuring the acceleration voltage of the electron beam at the appearance of characteristic X-ray lines from the base. The use of an atmospheric electron probe with an X-ray spectrometer makes the measurement feasible for rapid industrial routine tests. The accuracy of the measurements is very high, the method is not restricted to any combinationof plating and base metal.—T.G.

The corrosion protective characteristics of decorative chromium plate W. H. Safranek, H. R. Miller, and C. L. Faust (*Plating*, 1960, **47,** May, 513–519) Among other items it was found that porosity in Cr plate is markedly reduced when its thickness is increased to 0·025 mil.; at a thickness level of 0·05 mil., or more, Cr deposited on smooth surfaces is essentially pore-free. The conditions for obtaining pore-free and crack-free Cr deposits are listed. Only crack-free or pore-free deposits give good protection, this in particular with undercoats of Ni.—T.G.

The development of duplex nickel plating M. M. Beckwith (*Plating*, 1960, **47,** April, 402–404) The steps in the development of duplex Ni during the last 15 years and the testing of the deposits by the CASS and Corrodkote tests are described.—T.G.

The life of galvanizing baths E. Vejmelka (*Hutník*, 1960, **10,** (3), 112–114) The principal factor affecting the life of the baths is shown to be the composition of the steel; the latter should have low C and Si contents. Welding technology and the use of suitable electrodes are also important.—P.F.

Present level of the technology of tinplating A. I. Vitkin (*Metallurg*, 1960, (1), 27–30) A review of the equipment and machinery available mainly in the USA for tin-plating by dipping and by the electrolytic process, and of Russian achievements in this direction.

Physical properties of sprayed metals W. B. Meyer (*Canad. Metalw.*, 1960, **23,** May, 41) A data sheet listing density, hardness, melting point, shrinkage, tensile strength, and finishing of the commonly used sprayed metals.—T.G.

Sprayed ceramic coatings J. A. Sheppard (*Eng. Mat. Design*, 1960, **3,** May, 288–290) Spraying with alumina and zirconia, the properties of the coatings and their uses are described.

The preparation and properties of iron–nickel films I. Tsu (*Plating*, 1960, **47,** June, 632–633) A chloride bath for the preparation of iron-rich films by electro-deposition is described. These films are isotropic as indicated by measurements of 60 cycle B–M loops. This behaviour is similar to that of the nickel-rich films described in the literature. However, the wall motion coercive force (Hc) is lower for the iron-rich films due to the relative magnetic properties of iron and nickel. The evidence presented shows that the anisotropic character of iron–nickel films does not depend solely on film composition. The addition of thiourea to the chloride bath causes extreme changes in the composition and physical properties of the plated films.

Corrosion protection by the use of zinc and the processes used for the coating M. Straschill (*Metall-Reinigung Vorbeh.*, 1960, **9,** July, 111–114) A brief review of the various processes for the application of zinc coatings such as galvanizing, electrodeposition, diffusion, and peen-plating.—T.G.

Metallic coating by electrolysis. Some general notes on the zinc-alkali bath A. Tomor (*Galvano*, 1960, **29,** Feb., 83–86) This article aims at providing a better understanding of the zinc alkaline bath process. Some of the possible causes of failure and ways of improving the process are discussed.

A preliminary study of the relationship between tin coating grain size of electro-tinplate and flow-brightening conditions C. J. Thwaites (*Metallurgia*, 1960, **61,** March, 113–121) Experimental work has been done on the use of a new electrotinplate flow-brightening unit, and the results are presented. The factors governing the grain size of the electrolytic tinplate have been investigated. It is suggested that the phenomenon of 'striping', produced by the use of high-pressure water jets in the quench tank, could be used to differentiate between the two sides of differentially coated tinplate.

Automatic grading of sheet metal F. I. Zenchenko (*Stal'*, 1960, (8), 732–733) Tinplate is examined for pinholes using photocells and by thickness using a Sr source of β-rays. Defective sheets are automatically diverted to a special baling position. The cutting and handling arrangements are also described.

Electrodeposition of copper from the pyrophosphate bath S. K. Panikkar and T. L. Rama Char (*J. Sci. Ind. Res.*, 1960, **19A,** June, 265–272).

Surface treatment by electrical processes: Processes for the pretreatment of steel parts and their plating with copper/nickel/chromium A. Strauch (*Technik*, 1960, **15,** Aug., 535–538) Electropolishing and plating of steel parts for decorative corrosion protection with Cu–Ni–Cr to a total thickness of 48 μ is described.—T.G.

Sprayed metal coatings G. A. Curson (*Brit. Weld. J.*, 1960, **7,** May, 312–317) The author describes the powder and wire spraying processes, the nature of the coating, surface preparation, protective coatings (e.g. Zn and Al) applied in this way, compound coatings, automatic plant, site work, and building-up work.

Production metallizing machines L. Manuel (*Brit. Weld. J.*, 1960, **7,** May, 323–326) The author outlines some of the considerations necessary when deciding the degree of automation required for any given machine and the requirements necessary to incorporate good metallizing practice. Some of the automatic metallizing machines now operating in full production are also briefly described.

Development of metal spraying methods and equipment S. Metelko (*Varilna Tech.*, 1960, **9,** (1), 13–17) This article reviews the metal spraying process from its beginnings to the present dealing with present problems. The work of the Institute of Welding, LRS, and similar international organizations in developing the process is described.

Reclamation by metal spraying W. E. Ballard (*Brit. Weld. J.*, 1960, **7,** April, 223–230) The author reviews the development of metal spraying processes, considers the various types of coating and methods of finishing available, and outlines the applications of the process.

A study of phosphate treatment of metals L. O. Gilbert (*RIALR* 56–2995; *PB* 130013, 1956, May, pp.66; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 122; no abstract).

A review of phosphate coatings for assisting cold extrusion H. A. Holden (*Sheet & Strip Metal Users' Techn. Assoc., Annual Proc.*, 1951–52, **5,** 173–186) The history, importance, and principles of the effect of phosphate coatings on the deep-drawing of steel are considered.

The influence of grit blasting on the rate of coating formation in room temperature phosphatizing solution J. Knanishu (*RIALR* 57–383; *PB* 130100, 1947, Feb., pp.26; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 122; no abstract).

Corrosion resistance by the use of plastics applied by modern methods D. Weichert (*Technik*, 1960, **15,** Aug., 539–542) A review of flame spraying and of the fluidized-bed application of plastics to steel parts for corrosion protection. The properties of a number of plastics are also described.—T.G.

Viscosity measurements of porcelain enamel ground coat frits J. E. Cox, D. M. Gerstner, and H. M. O'Rourke (*Am. Ceram. Soc. Bull.*, 1960, Feb., 78–81) Use of the Brookfield viscometer is described. Various commercial frits were examined.

Preparatory treatment of metal surfaces and application of paints for welding G. W. Sloof (*Pein. Pig. Ver.*, 1960, **36,** Aug., 452–462) The writer describes methods of avoiding corrosion of metal structures and treating non-fabricated or semi-finished materials and anti-rust protection. He also discusses the social and economic aspects of modern methods of preparing metal surfaces and the best working conditions in welding shops. Tests on paints for welding and particularly the influence of lead paints on opacity of the weld joint to X-rays and the composition of the fumes emitted during the operation are outlined. The article concludes by outlining the general requirements a paint for welding must possess.

Potentiometric study of priming paints for metal N. R. Bharucha (*Nature*, 1960, **187,** Aug. 27, 756–758) Single test panels are half coated with the paint and regarded as 'contact couples'. The types of curves obtained are shown and discussed (17 refs).

Paint coat and surface quality of the base metal L. Bierner (*Mitt. Forschungs. Blechverarb.*, 1960, (15–16), Aug. 10, 203–207) The

relationship between paints and surface quality of the base metal and its preparation is discussed with respect to a technically correct and economic rust prevention. Adhesion of the paint coat depends largely on the surface quality of the base metal, preparation of the surface is therefore one of the most important steps in corrosion and rust protection.

CLAD SHEET AND HARD FACING

Clad steels Colvilles Ltd (*Met. Bull.*, 1960, July, 47–49) The various types of clad steel, their applications; production methods, mechanical properties, and fabrication are reviewed briefly.—T.G.

Improved mixtures for hard facing I. I. Ickol'dskii and S. L. Cherkinskaya (*Svar. Proizv.*, 1960, (2), 32–35) Some new mixtures are suggested, a few of which are: 50%Fe–Cr, 50% iron powders; 60%Fe–Cr, 30% iron powder, 10% chromium boride; details of the hardness is obtained and of the metal structures are tabulated.

Automatic wear-resistant facing for large scale production A. P. Suahchenko (*Svar. Proizv.*, 1960, (3), 27–30) A method has been worked out for the automatic classification of components by means of transversal displacement which ensures great efficiency and fits in with the process of the automatic deposition of the alloy under the flux by a special proportioning device. This operates independent of any changes in the voltage or in the contour of the surface under treatment. The special proportioning device can introduce alloy components of different specific gravities and grain sizes separately into the layer of flux.

Wear-resistant facing with powder tape electrode O. A. Bakshi, E. F. Belousov, G. P. Klekovkin, V. M. Solovskoi, and T. V. Sumina (*Svar. Proizv.*, 1960, (3), 30–33) A new type of electrode is suitable for deposition of hard alloys on large surfaces, ensuring appreciable advantages such as high efficiency and excellent quality of the facing layer, exceeding by far the layer deposited by the carbon arc. The base metal is not fused to a great depth and the possibility is given for a wide control of the chemical composition and the hardness of the deposited layer with a substantial reduction in costs and an improvement in the working conditions. The operation may be carried out continuously or intermittently and the optimum conditions for these procedures have been worked out.

Adjusting the production of thermo-bimetallic sheet in coils A. S. Belorusov and Ya. S. Shvartsbart (*Metallurg*, 1960, (1), 25–27) Bimetal type TB–3 is composed of the active alloy N24Kh2 with heat expansion coefficient of $>20\cdot10^{-6}$/1°C and of the passive alloy N36 with a coefficient of $>1\cdot5\cdot10^{-6}$/1°C. The process has gone beyond the experimental stage and is explained in great detail.

Aluminized and chromized coatings change steel properties E. A. Brandes (*Product Eng.*, 1960, **31**, June 27, 31–33) The processes are described and the effects on grain size and decarburization which influence mechanical properties are explained.

Reconditioning traction chains of conveyors by welding-on hard alloys G. A. Chilaev (*Svar. Proizv.*, 1960, (5), 39–40) The best method for extending the service life of such elements is electric arc welding, depositing hard alloys on the eroded surfaces. T–590 electrodes 4 mm diameter operating with AC of 220 amp are recommended. The service life of restored components is increased by a factor of 5–6.

Basic information on vibration hard surfacing A. Jurek and J. Lukášek (*Zvaránie*, 1960, **9**, (5), 143–146) [In Czech] The principles and utilization of the method of vibration welding, in which the electrode alternately approaches and recedes from the base metal, are discussed. Its development in the USSR, and the present state of its utilization on weld repairs in Czecho-Slovakia are reviewed.—P.F.

Hard chroming J. C. de Miguel Coll (*Anales. Mec. Elect.*, 1960, **37**, March–April, 59–64) A general consideration of the hard Cr plating process, with its advantages and disadvantages is given. Details of the preparation for plating, and the characteristics of the plating baths and the deposits produced are supplied.—P.S.

Review of present hard chromium techniques P. Morisset (*Chrome Dur.*, 1959–60, 40–45) This article reviews the latest information on research being carried out on hard chromium in various countries giving a brief description and reference—covering chromium plating technique, properties of chromium deposits and industrial applications.

The applications of hard chromium in hydraulic turbines R. Kermabon (*Chrome Dur.*, 1959–60, 15–32) The many uses of hard chromium in hydraulics have substantially improved turbine wear resistance. The type of the parts has been extended with consequently less frequent dismantling and replacement. In addition initial efficiency is maintained for a much longer period.

Spray-gun metallization and hard chromium plating R. De Buyer (*Chrome Dur.*, 1959–60, 70–74) Spray-gun metallization can be combined with hard chromium plating to achieve results which would not be possible by either method alone. Spray gun metallizing is more suitable for thick replating of used machinery parts whereas hard chromium plating is to be preferred for surface hardening of friction surfaces. This article describes the interesting results obtained by combining these two methods.

Sprayed metal coatings for abrasion, corrosion and oxidation resistance G. R. Bell (*Brit. Weld. J.*, 1960, **7**, May, 305–311) The development of nickel chromium–boride–silicate alloys and powders is described, and the powder properties required for and the technique employed in, successful hard plating are discussed. Results of corrosion tests are given, and new developments are mentioned.

Hard facing with plasma spray guns E. A. Gerhold (*Brit. Weld. J.*, 1960, **7**, May, 327–330) The range of hard-facing materials should be extended by utilizing the heat developed by plasma gas. This paper reviews the various methods of obtaining plasma conditions suitable for flame spraying and describes the principles and operation of the new METCO Type MB plasma flame spray gun and some of the materials successfully sprayed by this equipment.

The deposition of titanium carbide coatings on steel W. Ruppert (*Metalloberfläche*, 1960, **14**, July, 193–198) After discussing the theory of the deposition of TiC from the gaseous phase on steel the author describes a study of the successful coating of a 2%C steel with TiC. The iron takes part in the reactions by forming the volatile $FeCl_2$, the adhesion of the coatings was good. The reaction requires a temp. of at least 930°C. Good coatings were also obtained on Cr steels and cast iron. The thermodynamics of the reactions involved are discussed. The rate of the reaction depends—at least at the beginning—on the composition of the material to be coated, particularly its carbon content (29 refs).—T.G.

Hard facing with 'Stellite' powders J. R. Gault (*Brit. Weld. J.*, 1960, **7**, May, 318–323) The author discusses the application of 'Stellite' alloys by the Spray Fuse and powder weld processes. The equipment required, the properties of the coating, and typical applications for these methods are given.

Bonding aluminium to steel. Part I R. E. Seal (*Prec. Met. Mold.*, 1960, **18**, June, 45–47) By the Al–Fin process a bimetallic casting of Al and steel produces a molecular bond between the two metals. A molten light metal alloy is cast against the prepared surface of a ferrous metal part. Any castable Al or Mg alloys can be bonded to grey malleable and austenitic cast irons, carbon, alloy, and stainless steels. A full account of the process is given.

POWDER METALLURGY

The beginnings and the development of powder metallurgy in Czecho-Slovakia M. Petrdlik (*Hutník*, 1960, **10**, (3), 111–112) The principal features of the development of production and research are surveyed.—P.F.

Sinterized material for magnets F. Núñez (*Rev. Ciênc. Apl.*, 1960, **14**, (73), 97–106) A sinterized material, from among those denominated as 'magnetically hard' and composed of iron and barium, is described as possessing remarkable properties, including outstandingly high value in the coercive field, great electric sensitivity, and low cost. The influence of sintering temp. of the size of grain and of the proportion in the mixture of the oxides exercised upon the magnetic properties of the magnets, and other properties, including stability of magnetism against external influences, temp., and the magnetic fields, are reviewed.—S.H.-S.

The growth and future of powder metallurgy K. H. Roll (*Prec. Met. Mold.*, 1960, **18**, June, 48) The writer gives a brief statistical illustration of the growth of powder metallurgy in the USA as evidenced by the distribution of iron powder consumption and the rise in US shipments of iron powder, copper, iron, and stainless steel powders are all expanding fields.

Segregation in homogeneous alloys during sintering G. Matsumura (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1960, **9**, March, 114–119) The neck between two sintered particles is shown to produce considerable segregation in certain cases in a completely homogenized solid solution. The examples are non-ferrous.

Iron powder produced by the H-iron process G. G. Karian (*AISI Reg. Tech. Meetings*, 1959, 287–302) The method used for producing 50 t of iron powder daily by direct reduction and use of the Hydrocarbon Research Inc. fluid bed technique at the Conshohocken, Penn. plant of the Alan Wood Steel Co. is described and some of the numerous types of product are indicated.

Designing for powder metal parts (*Mach. Des.*, 1960, **32**, July 7, 112–122) A general account of the design, production, and properties of iron, copper, and other powder sinterings including bearing materials and gears.

Guide to specifying metal-powder parts R. Talmage and H. L. Kee (*Prod. Eng.*, 1960, **31**, July 25, 56–59) Choice of materials, techniques for different structures, priority, and the sintered properties are discussed, and cost-comparison (for steel gears) is exemplified.

New powder rolling process S. Storchheim (*J. Met.*, 1960, **12**, March, 225) Powders are rolled in a conventional or vertical powder rolling mill in such a way that strip is obtained with almost 100% theoretical density. Applications described are non-ferrous.

Automatic deposition on sleeves for presses by powder wire in a carbon dioxide medium M. I. Raznikov and E. I. Bobrov (*Svar. Proizv.*, 1960, (2), 29–30) A special burner is described for depositing metal on the interior surface of sleeves for presses in a CO_2 atmosphere. It is in use at the Kamensk-Uralsk works for non-ferrous metals. It operates with a special machine. The chemical composition of some wire metals is given.

FERRITES, CERMETS, AND CARBIDES

Sintering kinetics of cermets in the presence of liquid phases B. Čech (*Hutn. Listy*, 1960, **15**, (4), 287–292) The contraction of various carbides and borides was studied in a vacuum apparatus during sintering, liquid phases being present. It is shown that present models of the sintering process considerably oversimplify the reactions occurring. Some of the variables affecting the sintering such as the adhesion of the liquid to the solid are not generally allowed for, though they are of considerable importance.—P.F.

Line-width and some magnetic properties of the system $Ni_{1-x-y}Cu_xCo_yFe_2O_4$ R. Wadas (*Bull. Acad. Polonaise Sci.*, 1960, **8**, (5), 241–243) [In English].

Line width in Ni–Cu–Co ferrites R. Wadas (*Archiwum Elektrotech.*, 1960, **9**, (2), 333–354).

PROPERTIES AND TESTS

Mechanical properties of SAE–8135 steel tempered and converted with more than one microconstituent T. Cescon (*Bol. ABM*, 1960, **16**, April, 359–373) The variations in mechanical properties of 8135 steel when submitted to tempering and converting in different conditions are described, and variations in their properties are explained by an interpretation of their microstructures.—S.H.-S.

Investigating internal friction in metal–ceramic substances. III. Effects conditioned by

plastic deformation B. Ya. Pines and Den Ge Sen (*Fiz. Met. Metalloved.*, 1960, (1), 91–99) Test material was prepared from compacted powders of electrolytic Cu (99·99% purity), carbonyl Fe and Ni, also of 99·99% purity. The grains were all of similar size, less than 53 μ, and the working lengths of the specimens 70 mm with 3 × 3 mm cross-section. Internal friction tests *in vacuo* (10^{-4}–10^{-5} mm) were carried out on a torsion pendulum operating at a frequency of 102 c/s. Temp. were measured to an accuracy of $\pm 1°$. Two maxima were observed in the curves for internal friction and plastic deformation against temp. The first, a low temp. maximum, appears also in annealed specimens and is due to diffusion of a viscous nature along grain boundaries. The second, a high temp. maximum, first observed in this investigation in Cu and Ni, is due to the plastic deformation and obviously related to the dislocations. The position of the second maximum changes slightly towards lower temp. and its height increases with an increased rate of plastic deformation.

The mechanical properties of special steels and alloys under high hydrostatic pressures V. A. Shapochkin (*Fiz. Met. Metalloved.*, 1960, (2), 303–305) A series of experimental findings is tabulated and also presented graphically. From it may be seen that in all materials investigated a considerable increase in the resistance to shear stress is observed under hydrostatic pressures. Even when pressures of the order of 10^5 kg/cm^2 are reached not only is no tendency towards the damping of this resistance observed but on the contrary the resistance increases at a greater rate.

Solubility of carbon in alloys of iron with chromium and silicon P. V. Gel'd and M. S. Petrushevskii (*Fiz. Met. Metalloved.*, 1960, (3), 473–475) The solubility of carbon was investigated in these alloys at 1 700°. The experimental melts were carried out in an atmosphere of well purified argon in covered graphite crucibles; after holding for 1 h, the alloy was put into water, crushed, and analysed. Tables have been drawn up showing the effect of Cr and Si on the solubility of carbon. The reduction of the solubility with increasing Si content is conditioned not only by the strengthening (and saturation) of the metal–silicon bonds, but also by a decrease of the distances between the particles and a reduction of the free volumes, both of which are essential conditions for solution to take place.

Investigation of the strength of hard alloy reamers for working on cast iron Chou Tzya-hao (*Vestnik. Mashin.*, 1960, (4), 58–60) The chemical composition of the cast iron was, total carbon 3·06% with 0·71% free C; 1·59%Si; 0·96%Mn; 0·153%P; and 0·066%S. Mechanical properties: UTS 24·3 kg/mm^2; Ultimate compression strength 84·6 kg/mm^2; impact strength 0·21 kg/cm^2, and hardness 195–210 H_B. The investigation was carried out on machine type 2135 with a travel of 50 mm after countersinking. Standard reamers used: 22–25 mm type 'FREZER'. All results are tabulated.

The resistance of the chromium–nickel steels to deformation M. A. Zaikov (*Izvest. VUZ Chern. Met.*, 1959, (11), 63–72) Special experiments are described of tensile loading, shrinking, and rolling different types of Cr–Ni steels in the temp. range of their stable phase composition, i.e. from 600 to 1150–1200°. The experimental temp. was obtained by cooling the specimens from the temp. at which a holding time of 10–15 min was required to even out their structure. The parameters of the dependence on the temp. of the monoaxial resistance to deformation and the carbon content; of the resistance to deformation and high temp. etc. are tabulated.

Fractographic assessment of quality of steels used for castings K. Stránský (*Slévárenství*, 1960, **8**, (4), 114–118) A statistical study was made of the relation between the appearance of fracture surfaces obtained in tensile tests, and variables such as the chemical composition and the technology of tempering and melting of carbon steels used for castings. Although fractographic examination is somewhat subjective, it is shown nevertheless to provide a rapid and important means of assessing steel quality.—P.F.

Fatigue testing of reinforcing steel bars of periodic sections T. Timoshuk and N. I. Nistratov (*Zavods. Lab.*, 1960, (5), 608–609) The fatigue limit of steel for reinforcing concrete in periodic sections must be measured on actual bars and not on flat specimens. An eccentric ram impact machine for the purpose is described.

A new hardness number and Meyer constants for steel M. S. Drozd (*Zavods. Lab.*, 1960, (1), 90–93) The new hardness number determined by means of a ball test does not depend on the conditions of the test but reflects the physical basis for the relation between the load on the ball and the dia. of the indentation, identical with Meyer's rules. Meyer's constants a, n, and a_0 are identical functions of the new hardness number H and may be determined for any steel from the hardness readings.

Regarding certain effects of thermal treatment on the hardness of steel Yu. M. Ivanov (*Fiz. Met. Metalloved.*, 1960, (5), 797–800) The variations in the hardness values during the heat treatment of metal have an activation origin. At the basis of the temp.–time relation of the hardness of solid bodies lies the activation mechanism of the process of failure.

Apparatus for the full investigation of wear and fatigue of steel V. T. Sharai (*Zavods. Lab.*, 1960, (2), 241–242) A description of an apparatus evolved at the Kiev Institute of the National Air Fleet is given. It has a range of 30–7 000 rpm to investigate cylindrical specimens 17 mm dia. at a peripheral speed of 0·027 to 6·2 m/s., and 12 mm dia. at 0·015 to 4·4 m/s.

A method of investigating the effect of hardenability on the mechanical properties of alloy steel L. P. Kopp (*Zavods. Lab.*, 1960, (3), 310–312) The method explained permits the recognition of a relation between mechanical properties and hardness, thus avoiding the effect of the non-uniform deformation in the preparation of the specimens. The method is similar to that of Wilkes, Avery, and Cook (*Trans. ASM*, 1947, **38**, 437) The specimens consist of special cylinders which after heating to the desired temp. are quenched in water at one end. Results obtained show that hardness, the limit of proportionality, and yield point fall with increasing distance from the quenched end, while UTS remains almost constant.

The ageing of austenitic boiler steels type 1Kh18N12T, EI 695P and EI 257 I. N. Laguntsov and V. F. Zlepko (*Teploenergetika*, 1960, (4), 38–42) EI 695P has the most stable structure and EI 257 the least. All these steels change their initial properties with ageing. The coarsening taking place in the process does not reduce the impact strength to critical values for any periods of service. During the initial period of ageing heat-resistance, impact strength, structural stability, physical properties, and the tendency to intercrystalline corrosion alter more intensively than they do later. The changes in the electrical resistance may be used for controlling the structural alterations during ageing.

Influence of mass on mechanical properties of cast steel J. F. Wallace (*WAL* 311/17; *PB* 127569, 1949, Feb., pp.58; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 123; no abstract).

Metallurgical testing of boron steels C. L. Dotson and J. R. Kattus (*WADC TR* 53–439; *PB* 129526, 1954, Oct., pp.248; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 122; no abstract).

Metal-testing machines and instruments (*Iron Steel Rev.*, 1959, **3**, Aug., 25–31) Very brief descriptions of various Russian hardness, impact, tensile fatigue, and spring testing machines are given.

Mission of IRSID in research activities of the French iron and steel industry M. Allard (*Tetsu to Hagane*, 1960, **46**, Jan., 54–59) The work of the Institut de Recherche de la Sidérurgie, and associated bodies, is surveyed.—K.E.J.

A.N.C.C., A.S.M.E. and Swedish Standards for the calculation of pressure containers of plated sheets covered with stainless steel (*Acciaio Inossid*, 1960, **26**, (6), 261–270).

Toughness of metals B. H. D'Entremont (*Mét. Constr. Méc.*, 1960, **92**, June, 483–489) Bi-axial compression stresses, tri-axial tensile stresses, Mohr's circle, the intrinsic curve of the yield point, the mechanics of rupture, brittle metals, and tough metals are briefly discussed. (July, 539–546) A comprehensive review: including rupture through increasing stress; through impacts and alternating stresses; also composite materials, detailing case-hardening, triplex steel, stainless plated steels, and metallic armatures (carcasses). Bronze brazing is discussed and a table of test results obtained by the PROT Universal Static machine on limestone, concrete, and 15 different metals and alloys is presented.

On the fracture of metals M. Uemura (*Bull. JSME*, 1958, **1**, (1), 7–13) In part I, fracture criterion, two types of fracture, (1) shear, (slip, ductile), and (2) cleavage (tensile, brittle) were analysed and compared, the two major effects on fracture, triaxiality of stress and plastic strains preceding fracture being formulated mathematically. In Part II, tensile fracture tests were made on mild steel cylindrical bars having circumferential hyperbolic notches. Various fracture behaviours are explained and notch brittleness is discussed.

Developments in electrographic printing H. R. Miller and E. B. Friedl (*Plating*, 1960, **47**, May, 520–527) The electrographic printing method for evaluating porosity and cracking in protective-coating systems on metals is described and illustrated. Electrographic printing makes use of a small direct current to transfer ions from the base metal through discontinuities in the coating to a chemically-treated dye-transfer paper. Colour changes in the paper precisely locate cracks and pores in the coating.

On the elastic behaviour of materials A. Giet (*Compt. Rend.*, 1960, **251**, July 18, 327–329) Work with a double pendulum apparatus is briefly described. Steels were included.

Tracing of surface defects on steel products by means of artificial blowholes K. Kajiyama (*Tetsu to Hagane*, 1960, **46**, Jan., 25–29) 'Seamy' defects on round bars and sections tend to appear on most of the parts which correspond with the wider side of the rectangular cross-section of the ingot, and their development is greatly affected by the initial roughing conditions.—K.E.J.

Investigating internal friction in metal–ceramic substances. II. The Cu–Ni–Fe ternary system B. Ya. Pines and Den Ge Sen (*Fiz. Met. Metalloved.*, 1960, (1), 86–90) The tests were carried out under torsion cycles on powder specimens of this mixture. Six maxima were observed on the temp. curves for internal friction, apparently due to the diffusion of atoms along grain boundaries. Three of these peaks correspond to the contact processes between similar grains and the three others to contact between different grains. The temp. corresponding to these peaks agree with those found in the three binary systems composed of these elements.

An internal friction peak due to slow moving dislocations in iron–nitrogen alloys R. Rawlings and P. M. Robinson (*Acta Met.*, 1959, **7**, Oct., 659–663) A small peak in the internal friction-temp. curve has been observed in Fe–N alloys close to the Snoek peak. Evidence is put forward suggesting that this peak is due to slow moving dislocations.—A.G.

Room-temperature recovery of internal friction and elastic constants in freshly quenched steels C. E. Beaulieu, A. Dubé, and G. Letendre (*Trans. Met. Soc. AIME*, 1960, **218**, June, 558–566) An experimental study has been made of the time dependence of internal friction and modulus of rigidity in freshly quenched steels at room temp. The effects of frequency, composition, and various thermal treatments are given. The kinetic laws observed cannot be fully explained by the so-called first stage of tempering and the transformation of retained austenite. It is suggested that the observed phenomena are due to the progressive immobilization of dislocations introduced by the martensitic transformation.

Dislocations in metals. Theory and applications A. Roos (*Mét. Constr. Méc.*, 1960, **92**, July, 517–528) A review of distortion, rupture, and dislocation in crystalline structures, covering distortion during tensile tests, the influence of impurities, the interaction of defects and dislocations, and the effects of

strain hardening. Mott and Nabarro's theory is compared with that of Orowan, and the use of optical electronic examination and its applications is discussed.—S.H.-S.

Microscopical observations of dislocations M. Doi and J. A. Cintra (*Bol. ABM*, 1960, **16**, July, 519–555) A review of the observations made in the literature, and a discussion of them, is presented (42 refs).—P.S.

Stacking faults in iron–manganese and cobalt–nickel J. Spreadborough (*Acta Cryst.*, 1960, **13**, Aug., 603–605).

Possible coexisting order and disorder in Fe_3Al A. U. Seybolt (*Trans. Met. Soc., AIME*, 1960, **218**, June, 570) The possibility of coexisting order plus disorder in Fe_3Al was investigated by subjecting a wire of 22 at.-%Al, balance Fe, and 0·0513 cm in dia. to electrical resistivity measurement in a vacuum as a function of temp. between 300 and 800°C. The result was not conclusive and the suggestion of coexisting order plus disorder in Fe_3Al must be considered tentative until confirmed by high temp. X-ray examination.

Kinetics of ordering in Fe_3Al R. Feder and R. W. Cahn (*Phil. Mag.*, 1960, **5**, April, 343–353) Resistance changes due to thermal treatment of Fe_3Al have been measured and the annealing kinetics analysed, when it was found that increase in long-range order caused a large decrease in resistance and that the rate at which ordering occurs is a function of the initial quenching temp. All curves were fitted to the standard rate equation giving an order of reaction $n = 2·2$ for specimens quenched from 620°C and $n = 1·5$ for those quenched from 530°C. The activation energy from resistivity kinetics was much lower than the mean activation energy for diffusion.—S.H.-S.

Internal stresses in hardened and hardened-and-tempered hollow steel cylinders H. Bühler (*Stahl Eisen*, 1960, **80**, Aug. 4, 1088–1089) The author summarizes the results of recent measurements of the internal and residual stresses in stepped hollow steel cylinders after various types of heat-treatment. It is shown that in large forgings for turbine shafts and the like the distribution of the internal stresses after heat-treatments depend on the outside dia. if the inside dia. is uniform over the whole length. In the thicker parts, high tensile stresses were found at the inside wall whereas in the thinner parts these stresses were almost nil. To reduce the risk of crack formation during machining it is recommended that the outside should be machined first and then the borehole.—T.G.

Activity of oxygen in liquid iron–phosphorus alloys D. Dutilloy and J. Chipman (*Trans. Met. Soc. AIME*, 1960, **218**, June, 428–430) The equilibrium of gaseous H_2O–H_2 mixtures with liquid Fe–P alloys in the range 0–3%P is used to establish the increase in the activity coefficient of oxygen in the presence of phosphorus. Two different sampling techniques are used.

Thermodynamic interaction parameters of elements in liquid iron M. Ohtani and N. A. Gokcen (*Trans. Met. Soc. AIME*, 1960, **218**, June, 533–540) Thermodynamic interaction parameters of elements $\epsilon_3^{(2)}$ for dilute binary solutions of a component '2' in liquid iron, i.e. $\epsilon_3^{(2)} = \delta \ln f_3/\delta N_3$, where f_3 is the activity coefficient and N_3 the mole fraction, and $\epsilon_3^{(3)} = \frac{\delta \ln f_3}{\delta N_3}$ for dilute ternary solutions of '2' and '3' and the carbon saturation parameter $\zeta_o^{(3)} = \left(\frac{\delta \ln f_3}{\delta N_3}\right)\frac{N_C}{NFe}$ for $N_3 \to O$ are critically examined and correlated. It has been found that the interaction parameters and the atomic numbers of alloying elements follow regular periodic patterns.

Investigating the thermodynamic properties of solutions of carbon in liquid iron Sui Tsen-tsi, A. Yu. Polyakov, and A. M. Samarin (*Izvest. VUZ Chern. Met.*, 1959, (11), 3–12) From measurements, *in vacuo*, of the rate of vaporization of iron in liquid alloys of the Fe–C system, the numerical value of the activity of carbon between 1550 and 1600° has been deduced, for all concentrations. It has been established that solutions with low carbon content (up to $N_c \approx 0·05$) show weak negative deviations from Raoult's law, and those with concentrations above this figure, up to saturation, show positive deviations. Alloys with low carbon content show only a weak tendency to chemical interaction while in alloys with higher concentrations forces predominate which repel the carbon. These forces increase with increased carbon concentration.

Application of the Gibbs free energy equation to gas in binary and multi-component systems N. A. Gokcen (*Rev. Mét. Mém. Sci.*, 1960, **57**, April, 261–264) The expression $\ln \gamma_1/\gamma_3 = Ax_2$ is derived from the Gibbs free energy equation, where γ_1 represents the activity coefficient of the slightly soluble gas, γ_2 that of the component 3, x_2 the molecular fraction and A a constant. By means of this equation the activity coefficients of the metals in binary systems can be determined from the gas solubilities, or it may be used to determine the gas solubilities. Examples are given (20 refs).

Experimental relations between pure shear, tension and compression in the plastic domain Y. Sato (*Bull. JSME*, 1959, **2**, Feb., 107–118) Experimental work on mild steel, Al, and brass is described and the results are compared and discussed, with the conclusion that stress-strain relations between tension and compression are the same, and those between pure shear and tension are not the same, stress under pure shear being about 14% higher than that under tension in all plastic domains.

A theory of catastrophic shear fracture in ductile materials F. A. McClintock (*AFOSR TN-57-450; PB 129554*, 1957, July, pp.29; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 121; no abstract).

Plastic deformation in simple tension, practical consequences P. Azou (*Rev. Mét. Mém. Sci.*, 1960, **57**, June, 481–491) The phenomena encountered in simple tension are examined, together with the mathematical representation of the experimental curves obtained. The mechanism of simple tension is considered (23 refs).

The tensile properties of some engineering materials at moderate rates of strain R. F. Steidel jun. and C. E. Makerov (*ASTM Bull.*, 1960, July, 57–64) Cold-rolled steel and non-ferrous metals were tested with a standard Baldwin machine and with a modified Charpy impact tester arranged to eliminate bending. Yield strength increased with strain rate in all cases, but most for the steel, 72·9%.

Exhaustion of ductility of E-steel in tension following compressive prestrain D. C. Drucker, C. Mylonas, and G. Lianis (*Weld. J.*, 1960, **39**, March, 117s–120s) It was found that pre-compression generally caused a considerable reduction in ductility of tensile specimens.

Yield point depends on the rate of strain. Its theory Y. Nakagawa (*Bull. JSME*, 1959, **2**, (8), 501–503) A new theory and equations are presented based on a rheological spring- and dash-pot model.—S.H.-S.

A comparison between experiments and Nakanishi's theory on the yield point of mild steel cylinders under pressure Y. Sato (*Bull. JSME*, 1959, **2**, (8), 504–508) Tests are described and discussed which claim to justify Nakanishi's new theory on the yield-point of mild steel, concerning the relation between pressure and strain, as well as the stress at the yield point throughout the whole range of γ.

Yield behaviour of unplasticised polyvinyl chloride (P.V.C.). Analogy with yielding of mild steel Y. Nakagawa and S. Okuda (*Bull. JSME*, 1959, **2**, Feb., 97–102) In two steps, initial yield being followed by progressive yield, comparison was made with upper and lower yield-points in mild steel. Yield was affected by speed of stretch V_{st}, the yield strain being S and velocity of propagation of the plastic wave front being C: V_{st}–C_t. While these analogies may have a bearing on the yield behaviour of mild steel, it is also suggested that this approach may be applied to thermoplastics such as polythene and nylon.

Destructive tests on prototypes of steel structures L. Finzi (*Construzioni Metal*, 1959, (5), reprint, pp.8) The reasons in favour of carrying out breaking tests on prototypes of steel structures are discussed. Test equipment is described, details of operational methods and reports on tests are given.

Assessing yield-point and U.T.S. on cylindrical specimens of welded pipe joints D. A. Pomazan (*Zavods. Lab.*, 1960, (4), 483–484) Cylindrical specimens with ends of larger dia. were compared with the normal flat specimens, also with enlarged ends, in tests for yield-point and UTS. The scatter of plots fluctuated between 0 and 2·5 kg which can be explained by the inaccuracy of the specimens and by the different degrees of work-hardening they have sustained. The advantage claimed is that the cylindrical specimens are about half the weight of the flat ones.

The kinetics of the plastic deformation and failure of steel in bending I. A. Razov and E. M. Shevandin (*Fiz. Met. Metalloved.*, 1960, (1), 133–139) The specimens were made of 8XL–1 steel. In the testing of notched specimens the first macrocracks of the order of 0·2–0·3 mm appeared at the notch long before the load attained its maximum value. The important role played by the elastic energy contained in the stress system has been demonstrated from a comparison of diagrams for bending and tensile loading. It has also been shown that the first cracks appear, with bending, in the surface layer where a three-dimensional stress system acts, and they then continue to develop in depth.

The toughness of reinforcing bars T. Wyss, G. Morini, and B. Bernardi (*Schweiz. Arch.*, 1960, **26**, June, 221–232) The bending behaviour of reinforcing bars—particularly profile bars—was studied with respect to SIA specification No.162, 1956. It is shown that these specifications are ambiguous and do not allow a sufficient appraisal of the bendability of reinforcing bars. New requirements for amendment of these specifications are suggested.—T.G.

Tensile testing of materials at impact rates of strain J. Harding, E. O. Wood, and J. D. Campbell (*J. Mech. Eng. Sci.*, 1960, **2**, June, 88–96) The techniques used in the construction of dynamic tension-testing machines are reviewed and the problems involved in obtaining reliable tensile stress-strain curves at high strain rates discussed. A new apparatus designed to give accurate stress-strain curves in tension at strain rates of the order of 1000 per sec is described. Some experimental results obtained with this apparatus are presented both for materials that exhibit a definite yield point and for those that do not (23 refs).—T.G.

A new fracture test for alloy steels D. L. Newhouse and B. M. Wundt (*Met. Prog.*, 1960, **78**, July, 81–82, 166, 168) A brittle boundary layer is produced in laboratory test pieces by nitriding impact specimens. In this way fracture toughnesses and appearances similar to those of large notched discs are obtained.

Studies of load-time relations under the Charpy impact test. I. On the transition temperatures of mild steel S. Sakui, T. Nakamura, and M. Omori (*Tetsu to Hagane*, 1960, **46**, Feb., 140–146) Results are given for a killed steel containing 0·17%C tested in a miniature Charpy machine. The transition temp. is very sensitive to the heat-treated state, e.g. it is −70°C for 700°C annealing but 10°C for 800°C annealing. Specimens quenched from above the transformation point had no definite transition temp. A rapid increase in max. load with decrease of testing temp. was always observed in the transition temp. range.—K.E.J.

The behaviour of malleable cast iron under impact stressing K. Löhberg and H. G. Trapp (*Giesserei*, 1960, **47**, June 2, 283–287) Results of comprehensive impact tests on white heart and black heart malleable cast iron were evaluated statistically. It was shown that the impact strength is dependent on the alloy contents (Si, Mn–S ratio) and structure (proportion of pearlite and amount and form of temper carbon).

Effect of residual aluminium on impact toughness of steel at low temperatures E. I. Rabinovich, M. K. Skul'skii, and K. K. Biktagirov (*Metallov. Term. Obra. Met.*, 1959, (3), 25–28) Effects of up to 0·02%Al were examined, including quality of deoxidation and method of Al introduction. The Al was determined spectrographically and microstructures are shown. Cold-shortness depended on Al content and grain size. More rapid cooling gave finer grain and lower cold-shortness.

Critical cold-shortness temp. fell with increase of Al up to 0·02%. The impact strength at 0° to −40° with only traces of Al was negligible.

K-factor for impact loading S. W. Kaye (*Product Eng.*, 1960, **31**, Aug. 22, 53) A corrected formula taking into account the kinetic energy dispersed is given, with curves showing the value of this k-factor.

Notch sensitivity in high-strength sheet materials G. M. Orner and C. E. Hartbower (*Weld. J.*, 1960, **39**, April, 147s–159s) The significance of notch sensitivity, and techniques for its measurement are discussed. In particular, the application of the Charpy test, using standard V-notch specimens, to high strength steel and Ti sheet is considered.

Cold deformation P. Blain (*Centre Doc. Sidér.*, 1959, **16**, (8), 1801–1807) In cold working the relative deformation, a dimensionless quantity, is the important factor. The relative merits of different formulae for determining the degree of deformation are considered.—A.G

Preliminary investigation of the emanation from cold-worked metals F. H. Vitovel (*WADC TR-54-20, PB* 130367, 1954, July, pp.31; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 121; no abstract).

Malleable iron: fatigue and impact effects [Malleable Founders Society] (*Mach. Des.*, 1960, **32**, Jan. 7, 124–126) Condensed from the handbook *Malleable Iron*.

Correlation of the alternating stresses required to initiate and propagate a fatigue crack in mild steel N. E. Frost (*Nature*, 1960, **187**, July 16, 233–234) A parameter for crack propagation under cyclic load (zero mean load) depending on the cube of the stress and the crack length is developed and is correlated with the plain fatigue limit.

Micro-structural observation on fatigue fracture of metals S. Owaku and S. Morikawa (*Bull. JSME*, 1958, **1**, (2), 129–133) A brief description of the progress of fatigue fracture of mild and hard steels with illustrations of structural changes as the fractures develop.

A study on the fatigue strength of carbon steels under multiple repeated stresses T. Kori and S. Sasaki (*Bull. JSME*, 1960, **3**, (10), 281–286) A study in which an equation is derived expressing the relation between rotary bending stresses and the number of stress repetitions under multiple repeated stresses on two levels.

Some experiments on fatigue life under diaxial and triaxial stresses Y. Kawada, Y. Sekido, and S. Sasaki (*Bull. JSME*, 1960, **3**, (10), 275–281) In tests on 0·07% and 0·25%C steels the fatigue life was prolonged by secondary and tertiary stresses regardless of whether they were higher or lower than the primary stress. In a 0·47% high-carbon steel, fatigue life was shortened by secondary and tertiary stresses when lower than the primary stress but was prolonged when they were higher.

Influence of rest in stress alternation on the fatigue properties of low carbon steel at elevated temperatures S. Taira, Y. Murakami, and R. Koterazawa (*Bull. JSME*, 1960, **3**, (10), 242–246) In tests on 0·15%C steel at 450° and 300° with a frequency of alternating stress 1500 cpm, the influence of rest on fatigue strength was found to be practically negligible.

Influence of frequency of stress cycles on fatigue at elevated temperatures S. Taira and R. Koterazawa (*Bull. JSME*, 1960, **3**, (10), 235–241) Rotating-bending fatigue tests under constant strain amplitude on a 0·55%C steel and a 13%Cr steel at temp. 450–600° and with frequencies of stress cycles of 170 and 1500 cpm are described, with characteristics similar to those of low-carbon steel studied previously. Fatigue at elevated temp., it is suggested, is closely related to plastic deformation of the material under alternating load.—S.H.-S.

Changes in properties of steel caused by low-temperature quenching T. Sakurai, T. Kawasaki, and Y. Kita (*Bull. JSME*, 1958, **1**, (2), 114–119) Tests on three carbon steels showed greater increase in fatigue strength with notched specimens than with plain, and reasons for this development are advanced and discussed.—S.H.-S.

Non-propagating cracks in fatigue of metals M. Kawamoto and K. Kimura (*Bull. JSME*, 1960, **3**, (9), 41–47) A new hypothesis is advanced to explain the behaviour of non-propagating cracks. The relationship between the conventional fatigue limit for the initiation of the crack, the depth of the non-propagating crack, and the cubical fatigue strength reduction factor are derived and discussed. It is considered that the material at the tip of the crack is stronger in the mass than at the surface. Theoretical values are in close agreement with those obtained under standard experimental conditions.—S.H.-S.

The effect of atmosphere on fatigue strength of carbon steels at elevated temperature K. Endo (*Bull. JSME*, 1960, **3**, (9), 76–80) Fatigue tests of C steels were carried out at 550° under rotating bending and repeated torsion in town's gas to reduce oxidation. Fatigue strength was greater in gas than in air under low stress but corrosion fatigue due to oxidation was good in air at high temperatures. Under high stress strength was lower in gas than in air and the S–N curves intersect. It is considered that these observations may be due to H_2-embrittlement resulting from H_2O decomposition. Similar results occur in stress-rupture tests when the shape of the S–N curve is changed under oxidative action, indicating the existence of an endurance limit.—S.H.-S.

Fatigue and dynamic creep properties of 13 Cr steel at elevated temperature under combined stresses of static tension and alternating bending S. Taira, R. Koterazawa, and M. Inone (*Bull. JSME*, 1959, **2**, (8), 508–513) Tests made under simulated service conditions on turbine blades, showed (1) alternate bending stress superimposed on static tensile stress reduced fatigue life, (2) this combination does not always increase creep strain, and (3) the hardening effect of materials by stress alternation explains hindrance of increase in creep strain by alternating bending stress.—S.H.-S.

Traction-compression fatigue tests on low-alloy steel test pieces nickel plated and then chromium plated J. Tigeot (*Chrome Dur.*, 1959–60, 59–69) Several series of tests on cylindrical-shaped electrolytically nickel and chromium plated Cr–Mn steel are described which showed that the sub-coating of Ni under the Cr plating did not itself change the fatigue limit of the basic metal but did not reduce the unfavourable influence of the Cr plating on this fatigue limit. However in the case described the reduction in the fatigue limit due to the Cr plating was attenuated by heat treatment at over 200°.

Influence of the initial state of a metal on the development of its crystal structure during high-temperature fatigue J. de Fouquet (*Rev. Mét. Mém. Sci.*, 1960, **57**, March, 232–240) The influence of initial deformation in fatigue or in tension or preliminary polygonization on the development of crystal structure at elevated temp. is investigated; optimum conditions for grain growth have been obtained during fatigue stressing at 700°C.

Fatigue strength of a bar with a cotter hole H. Yoshitake (*Bull. JSME*, 1959, **2**, May, 306–310) In rotary bending fatigue tests on bars of S40C with rectangular cotter holes, experiments showed the notch-factor β of a bar with extruded circular hole to be approx. 1·45, while β of a bar with a rectangular cotter hole is 1·74, so that an extruded circular cotter hole is advantageous and is recommended for practical use.—S.H.-S.

Fatigue life of metallic materials under varying repeated stresses of two different stress waves T. Nishihara and T. Yumada (*Bull. JSME*, 1958, **1**, (1), 1–6) Soft materials, 0·22% carbon steel and super-duralumin were tested under varying repeated bending of two bending stress waves and gave good agreement with equation $Z_\lambda = 1/(1/N_1 + 1/N_2)$ through the whole range of λ. For 0·61% carbon steel, failure due to fatigue was only caused by the first stress waves.—S.H.-S.

Fatigue strength of induction-hardened test-piece with crack H. Nakamura, T. Amakasu, and S. Ueda (*Bull. JSME*, 1958, **1**, (3), 227–232) Rotary bending tests upon specimens of 0·18%C carbon steel, some plain and some with cracks, in two cases, both non-heat treated and induction-hardened, are described. The fact that cracks produced do not propagate further is advanced as a reason for the rise in fatigue limit in notched specimens of induction-hardened steel. Conversely the reduction rate of the crack is apparently less in the reduction-hardened steel. These seemingly contradictory facts are discussed.—S.H.-S.

Fatigue strength of steel specimens with artificial cracks H. Ouchida (*Bull. JSME*, 1958, **1**, (3), 233–239) Fatigue tests upon artificially cracked specimens of mild steel, 0·45%C steel, 13%Cr steel, and Ni–Cr steel under rotary bending are described and results discussed, together with the effect of the shot peening process upon cracked specimens.

Fatigue phenomena under rolling contact accompanied by sliding J. Akaoka and K. Hirasawa (*Bull. JSME*, 1959, **2**, Feb., 43–50) A survey covering various specimens and their testing results, fatigue diagrams, and generations and progress of cracks and affecting factors, followed by a brief summary of theoretical considerations.—S.H.-S.

Fatigue tests of metals at ultrasonic frequency J. Awatani and H. Miyamoto (*Bull. JSME*, 1959, **2**, Feb., 111–115) Equipment is described which is claimed to have an advantage over conventional fatigue machines, in that stress alternations up to 10^9 reversals can be made within ~1h. Metal samples at the resonant condition were subjected to alternating stresses above the fatigue limit by means of a magnetostriction transducer, through an exponential brass horn, and fatigue properties of various metals were investigated by this method, with water cooling to avoid temp. rise in the samples.—S.H.-S.

Symposium on fatigue of welded structures: Foreword R. Weck (*Brit. Weld. J.*, 1960, **7**, March, 161) The objects of the symposium, and the scope of the papers presented, are discussed.

A systematization of fatigue strength values of mild steel welds A. Neumann (*Brit. Weld. J.*, 1960, **7**, March, 162–168) Based on a quantitative formulation of Stüzzi's fatigue strength theory, a systematization of the fatigue strength values of all types of welded joints in mild steel has been developed. A great many test series were evaluated with the aim of establishing fundamentals for calculating dynamically loaded welded joints.

Fatigue strength of butt welds in mild steel R. P. Newman (*Brit. Weld. J.*, 1960, **7**, March, 169–178) The methods of fatigue testing of welded joints are discussed, and the factors that influence the fatigue strength of the various types of butt weld are considered. Typical data are quoted, both for comparison with design rules, and to show the spread of practical results.

Fatigue strength of fillet welded joints in steel T. R. Gurney (*Brit. Weld. J.*, 1960, **7**, March, 178–187) The author compares, British, US, USSR, and West German design specifications, and considers the factors that influence fatigue strength in this type of weld. Work in progress on improvements is also mentioned.

Increasing the fatigue strength of butt-welded joints W. Gilde (*Brit. Weld. J.*, 1960, **7**, March, 208–211) The use of plastic coatings to increase the bending fatigue strength of notched and welded specimens is described. The improvement may be as much as 75%.

Metallurgical aspects of future research on fatigue of welded structures W. D. Biggs (*Brit. Weld. J.*, 1960, **7**, March, 212–216) It is suggested that experimental data on the effects of grain size and dispersions are needed, as is an examination of possible heat-affected zone structures and their notched fatigue characteristics.

Programmed fatigue testing of full size welded steel structural assemblies J. G. Whitman and J. F. Alder (*Brit. Weld. J.*, 1960, **7**, April, 272–280) A new fatigue testing machine which was developed for testing full size welded structures, is described. Preliminary results of tests being carried out using this machine are given.

Fatigue of welded joints in high-strength steels J. E. Stallmeyer and W. H. Munse (*Brit. Weld. J.*, 1960, **7**, April, 281–287) The fatigue strength of welded alloy structural steels is considered, as well as the various factors which affect this strength. Transverse and longitudinal butt-welded joints and longitudinal and tee-fillet welds are discussed.

Evaluation of laboratory fatigue studies for welded structures W. H. Munse (*Weld. J.*, 1960, **39**, April, 172s–175s) Using welded bridges as an example, the author explains how laboratory results may be used to the best advantage in the design of welded structures subjected to periodic stressing.

Some effects of heat-treatment upon the impact-fatigue life of Ni-hard grinding balls R. H. T. Dixon (*JISI*, 1961, **197**, Jan., 40–48) [This issue].

Thermal fatigue investigations M. Cox and E. Glenny (*Engineer*, 1960, **210**, Aug. 26, 346–350) Tests especially of gas turbine blades by a simulated service conditions method using fluidized solids for heating and cooling are described. The work is in a preliminary stage but has already given useful results.

Fatigue crack propagation in torsion J. A. H. Hult (*AF OSR TN*–57–448; *PB* 129552, 1957, July, pp.16; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 120; no abstract).

Effects of hydrogen on low-cycle fatigue of high-strength steels G. Sachs (*WAL* 313/48; *PB* 133937, 1957, Jan., pp.47; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 122; no abstract).

Assessing the effect of greasing on the fatigue crumbling of steel G. S. Krivoshein (*Zavods. Lab.*, 1960, (3), 375–376) A modified four-roller friction machine suggested by Pavlov *et al.* (*Collection Mashinostroenie i priborostroenie Izd. AN SSSR*, 1958) capable of applying specific pressures of between 50000–75000 kg/cm^2 can assess rapidly the fatigue damage on a friction surface covered with different greases. Although there is a large scatter of results, a good correlation of the findings can be attained. A formula is evolved for calculating the required number of tests for a given standard of accuracy.

The effect of the dimensions of specimens on the long-term strength of 12KhMF and 1Kh18N12T steels V. N. Gulyaev (*Zavods. Lab.*, 1960, (2), 198–201) Up to 2500 h the long-term strength does not depend on the dimensions of specimens within a range of d = 5 mm and l = 12·5 mm to d = 20 mm and l = 100 mm. Neither does it depend, in tests to failure, on specimen dia. between 5 and 20 mm when constrictions form under moderate oxidation. A reduction of the dia. of 1Kh18N12T steel from 10 to 5 mm was not reflected in the fatigue limit for 100000 h at 600° although a reduction in the time before failure was noticed.

Fatigue phenomena in crane metal structures I. Balanescu (*Met. si Constr. Masini*, 1960, (1), 55–59) The lack of standards for calculating fatigue makes it imperative that such standards be immediately prepared. For comparison purposes Austrian and English standards are mentioned as well as BISRA reports on this subject.

Application of the Locati method for testing the fatigue limits of automobile parts C. Daubertes, J. Beuret, M. Renout, and R. Cazaud (*Rev. Mét.*, 1960, **57**, April, 337–346) The value and accuracy of the control method proposed by Locati using one test piece only were demonstrated, and it is shown that the fatigue limit agrees substantially with that of the conventional long-time test at 5×10^6 cycles.

Increased strength of carburized steel—some Russian work W. G. Cass (*Iron Steel*, 1960, **33**, March, 121–122) Work is described with the aim of explaining the nature of the fatigue strength of carburized steel; the residual stress of the carburized layer and its wear resistance with and without known residual stresses were measured (18 refs).

Portable creep-testing unit with autographic extensometer C. Wheatley and R. Grosvenor (*Metallurgia*, 1960, **61**, May, 225–230) A creep-testing machine is described for both creep and stress-rupture tests. The machine is capable of testing specimens over the load range 0·01–1 t and the extensometer records creep extensions autographically. The furnace temp. up to 1050°C can be controlled to within 1°C by an electronic control system. Block diagrams of the various electric systems and autographic creep strain records and results of stress rupture tests are given.—T.G.

Power law for creep B. J. Rigby (*Brit. J. Appl. Phys.*, 1960, **11**, July, 281–283) A model is discussed which gives the usual power law under constant load.

Creep of mild steel under periodic stresses of rectangular wave S. Taira, K. Tanaka, K. Ohji, and I. Harumoto (*Bull. JSME*, 1959, **2**, (8), 513–520) Creep tests with 0·14%C steel at 550° under a symmetric periodic rectangular stress wave showed that deformation under varying stress could be predicted with an error $\geqslant 10\%$ by the 'mechanical equation of state in the solid'.—S.H.-S.

Phenomenological theories of time effects in metals at high temperatures with special reference to primary creep B. C. Hoskin (*Dept. of Navy, Office of Naval Research, Techn. Rep. No.7*, 1958, Sept., pp.31) A review of the laws suggested for the mechanical behaviour of a metal at high temperatures in the case of constant ambient temp. and uni-axial stress. The Andrade formula is examined for small strains. Laws for permanent strains and recoverable strains in primary creep are suggested.

Creep of steel at room temperature H. Meyer (*Stahl Eisen*, 1960, **80**, Aug. 4, 1084–1088) This is a summary of a thesis in which the effect of room temp. Fluctuations and the effect of stress variations on the creep behaviour of steel were studied. The experiments and their results are reported and shown in graphs. The results are explained in terms of dislocation theory.—T.G.

Effect of stress reduction on secondary creep of mild steel T. Nishihara, S. Taira, K. Tanaka, and K. Ohji (*Bull. JSME*, 1959, **2**, Feb., 102–107) The behaviour of mild steel when stress is abruptly decreased for the secondary creep at 450°C is investigated and discussed, and is interpreted in the light of the authors' theory of plastic deformation.—S.H.-S.

The spectrum of activation energies for creep J. E. Dorn (*IER* 22–47; *PB* 128377, 1956, Sept., pp.50; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 121; no abstract).

Creep properties of 12–3 chromium–nickel stainless steel with titanium S. Terai (*Tetsu to Hagane*, 1960, **46**, Feb., 151–156) Creep-rupture tests for some 10000 h were made with type 321 steel in two soln.-treated conditions at 600°, 650°, and 700°C. Differences in rupture and creep properties are distinguished; treatment at 1200°C water-quenching gave higher rupture strengths than at 1050°C.—K.E.J.

A mechanism of deformation of metals at high temperatures with special reference to the tension test and the creep test S. Taira, K. Tanaka, and K. Ohji (*Bull. JSME*, 1960, **3**, (10), 228–234) The authors' prior theory of deformation, based on results of previous constant strain rate tension tests in 0·14%C steel at 450°, is here advanced further as the basis for a claim that it might be a general theory of deformation of materials at high temp., taking into account the effect of stress-and-temp. history.—S.H.-S.

Some crankshaft failures: investigations, causes and remedies R. Atkinson and P. Jackson (*Trans. Inst. Marine Eng.*, 1960, **72**, July, 269–288, discussion 289–304) Failures of Doxford 750 mm crankshafts are investigated and remedies are outlined.

Sclerometer for assessing mechanical properties of surface layers of metals and alloys M. M. Tenenbaum (*Zavods. Lab.*, 1960, (2), 236–238) The type St-4 sclerometer is described together with a method of calculating data from its readings.

On the Shore hardness tester (scleroscope) of type D. Motion of hammer T. Yoshizawa and S. Sekiya (*Bull. JSME*, 1958, **1**, Nov., 386–390) The use of a slightly modified Shore scleroscope and the method of measurement are described, the hardness values indicated on the hardness dial of the scleroscope being compared with the h.v. calculated from the height of rebound of the hammer measured by the optical method, and the results of the investigation are tabulated and discussed.—S.H.-S.

Control of surface hardness in carburized parts. The choice of the appropriate Rockwell scale H. Perez Vazquez (*Inst. Hierro Acero*, 1960, **67**, May, 521–531, Special Number) The most suitable loads for the determination of the Rockwell hardness of carburized parts have been established experimentally. It was found that the surface hardness of the various carburizing steels reached the same order of magnitude so the investigation was carried out on the three most commonly used types of steel (F-154, F-155, and UNI 14CN45). Graphs of hardness against thickness of the hardened layer for the six different Rockwell scales were determined and summarized to indicate the minimum case depth for which it is permissible to use each of them (19 refs).—F.S.

Ball indenters of tungsten carbide and of steel T. Yoshizawa (*Bull. JSME*, 1959, **2**, Feb., 123–131) A comparison of the use of WC balls with steel balls in the Brinell and Rockwell hardness tests in both softer and harder metals is presented and analysed mathematically.—S.H.-S.

Indentations for electron microscope investigations N. S. Alferova, A. I. Rizol', and V. P. Konovalov (*Zavods. Lab.*, 1960, (3), 312–313) A special device is described able to receive prepared specimens for observation *in vacuo* under the electron microscope of structural changes during deformation by bending. The specimens examined were of austenitic and pearlitic steels heated to 700°. Photographs with $\times 7000$ magnification can easily be taken, and the indentations show the actual deformation.

On the relation between Vickers hardness numbers and the force angles of pyramidal indenters T. Yoshizawa, and H. Nagao (*Bull. JSME*, 1960, **3**, (9), 36–41) Forty-five test specimens have been examined and the data show that the maximum error on the Vickers hardness number is $\geqslant 0{\cdot}2$–$0{\cdot}5\%$ if the technique described is followed.—S.H.-S.

Studies on the microhardness of metals: The dependence of the indentation hardness on the load A. M. Shams el Din and N. Ibl (*Schweiz. Arch.*, 1960, **26**, June, 246–250) [In English] The authors review existing theories of the dependence of the microhardness on the load and point out that no theory explains this relation satisfactorily. They propose a new theory postulating a back pressure from the metal surface. Meyer's law is corrected taking into account this material-dependent back pressure. The hardness is now defined as the effective load per unit indentation area. The results of hardness measurements on five metals were completely load-independent (18 refs).—T.G.

Dispersion hardening W. H. Meiklejohn and R. E. Skoda (*Acta Met.*, 1959, **7**, Oct., 675–676) The effect of the size and spacing of a dispersed second phase on yield strength has been determined for the iron–mercury system. The increase in yield stress was found to depend only on the volume fraction of the precipitate and the associated zones through which dislocations cannot pass.—A.G.

Hardness measurement of hard and brittle hardfacings K. Kirner (*Z. Metallk.*, 1960, **51**, July, 391–393) Samples of steel were hardfaced with layers of WC, Al_2O_3, and W at a thickness of about 250 μ and hardness tested with an automatic Tukon tester and with a low-load hardness tester by Reicherter. The loads were varied between 300 and 2000 g, the lowest loads always gave the highest hardness values. The results are presented in tables and graphs.—T.G.

Some aspects of the ageing of mild steels T. Greday (*Rev. Soc. Roy. Belge, Ing. et Ind.*, 1960, April, 218–229) The article discusses first the structures of various steels after heat treatment ranging from rapid quenching to slow cooling. The effect of impurities and alloying elements on these structures is also studied. Finally the preliminary results of the study of ageing after deformation by traction are given.

The relationship between silicon content and strain ageing of structural steel F. Erdmann-Jesnitzer, I. Sandmann, and G. Wünsche (*Technik*, 1960, **15**, Aug., 521–528) Five structural steels containing 0–0·44%Si were used in a study for the susceptibility to strain-ageing by static and dynamic loading. It was found that Si retards strain ageing. The optimum Si content was around 0·3%. Similar studies were conducted on P-alloyed steels, these showed a minimum in strain-ageing susceptibility at about 0·12%P (41 refs).—T.G.

Heat resistant austenitic high-phosphorus steel strengthened by ageing S. M. Vinarov, M. F. Alekseenko, and G. N. Orekhov (*Izvest. VUZ Chern. Met.*, 1959, (11), 83–87) P in austenitic steels ensures a considerable efficiency of ageing. Results of investigations here described show a definite relation between ageing and P content when the proportion of Ni is small (7–9%) and when the steel, in its structural condition is near to the boundary of austenite stability. The efficiency of ageing due to P increases in the presence of the δ-phase, but a Ni content of 18–19% cancels this effect.

Temper brittleness of steels L. D. Jaffe (*WAL* 801/1–4; *PB* 128953, 1949, Sept., pp.17; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 123; no abstract).

The brittle fracture behaviour of steel W. Rädeker (*Stahl Eisen*, 1960, **80,** Aug. 4, 1072–1083) Impact tests on a variety of steels of different origin and different ways of production at temp. between −190° and +200°C showed that there exists only a very few groups of steels as regards fundamental difference in brittle fracture sensitivity. Impact strength is very often no criterion of sensitivity to brittle fracture as other factors such as ageing, change of hardness, etc., play an important role. From the tests, which are described in detail, it is concluded that the specific impact work for one specified temp. cannot be used as a criterion for distinguishing steels with respect to brittle fracture sensitivity. It is suggested that comparison be made of impact strengths of various types of test-pieces at a high and a low (critical) temp. for an appraisal of a steel for brittle fracture.—T.G.

Test of incipient brittle rupture in reputedly ductile metals R. Pankowski-Fern, G. A. Homès, and J.-C. Bauwens (*Compt. Rend.*, 1960, **250,** March 28, 2368–2370) A new test is proposed based on two simultaneous conditions: (1) τ max. $> \tau^* = Re/2$, (2) and | grad τ max. | $> C$; τ max. being the max. tangential tension; τ^* a threshold of this size, linked to the nature and state of the metal; R_e the elastic tensile limit; C a constant depending on the nature, structure, temperature, and type of strain (single and slow, single and sharp, repeated, etc.). A crystallographic mechanism for such a flaw is presented, with supporting tests.—S.H.-S.

Supercooling Charpy specimens for the study of temper brittleness D. C. Buffum and F. L. Carr (*WAL* 801/1–5; *PB* 128239, 1950, Aug., pp.9; from *US Gov. Res. Rep.*, 1960, **33,** Supplement, April, 123; no abstract).

Long-time temper embrittlement L. D. Jaffe and D. C. Buffum (*WAL* 801/1–12; *PB* 127579, 1953, Sept., pp.12; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 123; no abstract).

Retrogression of temper brittleness L. D. Jaffe and D. C. Buffum (*WAL* 801/1–6; *PB* 127548, 1950, April, pp.11; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 123; no abstract).

Isothermal temper embrittlement of SAE 3140 steel F. L. Carr and N. Goldman (*WAL* 801/1–11; *PB* 127578, 1952, May, pp.18; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 123; no abstract.)

The effect of various heat treating cycles on temper brittleness L. D. Jaffe and D. C. Buffum (*WAL* 801/1–8; *PB* 127575, 1952, Feb., pp.20; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 122; no abstract.)

Effect of microstructure upon temper brittleness D. C. Buffum and L. D. Jaffe (*WAL* 801/1–9; *PB* 127577, 1952, May, pp.9; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 122; no abstract).

Effect of hardness on the level of the impact energy curve for temper brittle and embrittled steel F. L. Carr and M. Goldman (*WAL* 801/1–10; *PB* 127576, 1952, Jan., pp.11; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 122; no abstract).

Effect of hardness on temper brittleness D. C. Buffum and L. D. Jaffe (*WAL* 801/1–7; *PB* 127595, 1951, Jan., pp.8; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 122; no abstract).

Effect of grain size upon temper brittleness L. D. Jaffe and F. L. Carr (*WAL* 801/1–3; *PB* 127574, 1952, March, pp.17; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 122; no abstract).

Study of the cold brittleness of plain carbon mild steel. III. Fracture characteristics on tensile test of plain carbon mild steel S. Nakanishi (*Tetsu to Hagane*, 1960, **46,** Feb., 146–151) Normal and V-notched tensile specimens were tested, and the directionality of tensile strength, elongation, and reduction of area studied. The results are explained in terms of plastic deformation necessary for brittle fracture. Air-cooled specimens were more ductile than furnace-cooled (10 refs).—K.E.J.

Hydrogen absorption and embrittlement produced in iron by electrolytic charging W. Raczynski and M. Smialowski (*Bull. Acad. Polonaise Sci.*, 1960, **8,** (4), 209–214) [In English] Iron and mild steel wires, cold drawn and annealed at 800° in H_2 for 1 h were used. The degree of cold work required was applied by further drawing *in vacuo*. Electrolytic charging was carried out in 0·4N H_2SO_4 with 0·01 g/l As_2O_3 and embrittlement was observed in a torsion test. It was shown that H_2 distribution was not uniform across the section and evidence of three forms of hydrogen inclusion was found.

Hydrogen-embrittlement susceptibility of some steels and nonferrous alloys J. E. Srawley (*NRL Report*, 5392; *PB* 151937, 1959, Oct., pp.25) The criterion of embrittlement susceptibility used was the ratio of the lowest nominal stress at which an H_2-charged notched tensile specimen fractured within 100 h (the 'static-fatigue limit') to the notched tensile strength of the uncharged material. Of the ferrous materials tested, only cold-rolled AISI type 304 stainless steel was not susceptible; in general hardenable steels harder than Rockwell C 30 were very susceptible, with one exception (12 refs).

The embrittlement of metals by hydrogen. Influence of the crystallographic and electron structure P. Blanchard and A. R. Troiano (*Ref. Mét. Mém. Sci.*, 1960, **57,** June, 409–422) The embrittlement of several austenitic alloys by H_2 is investigated; embrittlement of an austenitic high-Ni Fe–Cr–Ni alloy indicates that structure is not the sole criterion of susceptibility to H_2 embrittlement. The theory of fracture due to Cottrell is applied to H_2 embrittlement, and a possible explanation, with some experimental supporting evidence, is advanced for the fact that only transitional elements have so far been embrittled by H_2 (29 refs).

Embrittlement by hydrogen and other interstitials A. R. Troiano (*Met. Prog.*, 1960, **77,** Feb., 112–117) H_2 embrittlement and the kinetics of delayed failure are discussed, and details of experimental work given.

Hydrogen embrittlement of phosphate-coated parts (sustained static loading of V-notched FS 4340 steel) T. J. Capello (*Technical Rep. NKF–T–35–56; PB* 128215, 1956, July, pp.12; from *US Govt. Res. Rep.*, 1960, **33,** Supplement, April, 124; no abstract).

The problem of residual stresses and the risks of brittle fracture in welded structures H. Gerbeaux (*Varilna Tech.*, 1960, **9,** (1), 1–12) As steel ductility decreases when temp. falls, brittle failure may occur when adaptation at the base of the notch becomes insufficient. The article studies experiments showing the decisive effect of residual stresses on a notched zone, residual welding stress, and stress relieving, and the main tests for the control of brittle behaviour (research and acceptance tests) are described. Knowledge acquired should make it possible for any given steel to draw an operating temp–total stress–thickness diagram with various safety zones, nil-imperfect or total requiring a certain stress relieving treatment depending on the case in question.

Plastic strain and fracture of steel specimens subjected to cylindrical states of stress. Application to the study of the hydrogen embrittlement of steel W. K. Liang, P. Azou, and P. Bastien (*Rev. Mét. Mém. Sci.*, 1960, **57,** March, 203–214) Cylindrical steel specimens have been tested in tension, and a simple method of determining the stress-strain curve proposed It is further shown that this stress-strain curve can also be used to determine the strain conditions in the case of a cylindrical state of stress. The results were applied to the determination of the influence of H_2 on the plastic and fracture characteristics of steel.

Application of dimensional analysis to the characteristics of wear under dry conditions K. Ebihara and K. Hayashi (*Bull. JSME*, 1960, **3,** (9), 6–12) Wear result is reduced to only two curves, geometrically, for any values of normal pressure and sliding speed, and Holm's theory is confirmed.—S.H.-S.

Influence of surface condition on friction resistance of hard chromium and mixed chrome-molybdenum platings P. A. Jacquet, J. J. Galbrun, and A. Popoff (*Chrome Dur.*, 1959–60, 46–58) Experiments were carried out to compare friction resistance of Cr plating surface polished electrolytically with a mechanically ground surface. It was found that the condition of the surface had a marked effect on friction resistance of hard Cr plate and that the life of the electrolytically polished plating was three to four times that of mechanically polished hard chromium.

Wear of an alloy cast iron cylinder liner K. Tarao (*Bull. JSME*, 1959, **2,** May, 230–237) Tests of alloy cast iron cylinder liners containing 0·65%Mo and 2·0%Cu, and cast centrifugally, carried out for wear in high-speed diesel engines on diesel cars of the Japanese National Railways, are described with reference to hardenability and other properties at high working temp.—S.H.-S.

Mechanical properties and wear resistance of gas carbonitrided auto parts in the USSR A. M. Tarasov and B. A. Stotsenko (*Trattamenti Term.*, 1960, **5,** March–April, 15–21) The article describes comparative tests on the depth case-hardened by carbonitriding, on the hardness of the cases and the core, on resistance to transversal rupture and wear resistance of various types of gear teeth for speed changes and back semi-axles for two types of automobile. The methods used for research and the composition of the steels used are given. The question of whether to use vertical or continuout furnaces for gaseous carbonitriding is dealt with and experience gained in their use and precautions to be taken are described.

Radioactive marking of steel balls for grinding tests G. G. Eichholz (*Department of Mines and Technical Surveys, Ottawa, TB* 12, 1959, Nov.20, pp.6) Steel balls were labelled with ^{59}Fe for investigations on life and wear of the balls under operating conditions in grinding circuits. The technique used is described in detail.

Stainless Steel: How to avoid seizing up Laboratorio Dell'Acciaieria di Avesta (*Acciaio Inossid*, 1960, **26,** (5), 225) In order to reduce the danger of seizing up, to which stainless steel is more susceptible than non- or low-alloy steels, the two surfaces should have a surface hardness higher than 400° Brinell. This can be obtained by: (1) using an austenitic chrome steel of 400°–450° Brinell hardness. Various Avesta steels are suggested. (2) Using Avesta 4535 quality (AISI 329) which can be hardened during precipitation treatment in the sigma phase.

How to avoid seizing up of stainless steel (*Acciaio Inossid*, 1960, **27,** (2), 413–415) A note from the Nickel Information Centre comments on an article appearing in *Acciaio Inossid.*, previous abstract. The note refers to practical tests carried out and published in 1953 by Sanczyn of Armco Steel Corporation which confirm that hardness is the main factor in resistance to seizing up. A table is attached which gives the results of these tests. From this it is seen that the best results are obtained using steels 27/4/1 at 400 Brinell against 27/4/1 at 400 Brinell and using 18/8 F hardness against 170 in 18/8 hardness 350. The note suggests that the use of hardening steel for precipitation in the state treated can contribute substantially to solving the problem as to the advantage that for austenitic of ferritic austenitic steels resistance to corrosion is sufficiently similar to that of steel type 301.

Non-destructive testing in the steel industry J. B. Austin (*AISI Reg. Tech. Meet.*, 1959, 1–18) A survey of the types of tests that are superceding radiography; viz., fluoroscopic sensitized paper, eddy currents, and magnetic

induction, ultrasonic tests, dye penetrants and magnetic particles, with remarks on test objectives and the application of preventative maintenance in the plant.

Non-destructive testing in a steel mill W. A. Black (*Met. Prog.*, 1960, **77**, Feb., 104–108) A seam depth indicator, a tube tester, and a portable ultrasonic unit are described.

Non-destructive tests on steels with special reference to stainless steels A. Brioni (*Acciaio Inossid.*, 1960, **27**, (1), 346–371) This article briefly defines non-destructive testing and outlines the factors which govern its use. The various methods are described with reference to welds, thickness control, and the detection and evaluation of defects in plates.

Plastically deformed steel in a weak magnetic field A. W. Sleeswyck (*Acta Met.*, 1959, **7**, Oct., 689–691) A letter. The effect of plastic deformation in tension and compression on the magnetic induction of a 0·16% carbon steel is described. The results obtained are attributed to the formation of non-propagating microcracks.—A. G.

The influence of carbon and nitrogen on the magnetic properties of silicon iron D. A. Leak and G. M. Leak (*BISRA Summary* 155, 1960, June, pp.3) (Derived from four reports in *Acta Met.* and *JISI*).

The Hall effect in the iron–nickel binary system W. Jellinghaus and M. P. de Andres (*Hierro y Acero*, 1960, **13**, Feb., 169–182) The working of the 'ordinary' Hall effect is described mathematically with two tables of Hall electric resistivity and magnetization constants in Fe–Ni alloys. A relation is then deduced between the Hall 'extraordinary' constant R_1 and the Curie temp., and is described with graphs of elastic tensions, of the formation of superstructures and of the influence of plastic deformations.—S. H.-S.

Relation between the magnetic induction in cold rolled transformer steel and final annealing conditions A. I. Belyakov and Yu. N. Yaroshenko (*Stal'*, 1960, (8), 750–752) Extended cooling time to 450° is recommended.

Ferromagnetism in Pd-rich palladium–iron alloys J. Crangle (*Phil. Mag.*, 1960, **5**, April, 335–342) Ferromagnetism has been detected, following upon Fallot's measurements, in disordered solid solution alloys of Fe in Pd at compositions down to 1·25 atomic % of iron. Data on magnetic moments and Curie points are presented, showing that part of the observed magnetic moment is associated with Pd atoms and is not completely localized in iron atoms.—S. H.-S.

The ferromagnetism of the compound γ–Fe_2Mn M. Asanuma (*J. Phys. Soc. Jap.*, 1960, **15**, July, 1343) (In English).

Crystallographic structure and anisotropy of the magnetic properties of hot rolled dynamo steel V. V. Druzhinin and G. V. Ignatova (*Fiz. Met. Metalloved.*, 1960, (3), 353–357) The difference in the types of crystallographic texture and anisotropy of magnetic properties is due to the reversing of the sheets in rolling. In sheets first rolled, the crystallographic structure is of the type (100) [110]. In sheets with reversed rolling this structure is more complex and is represented by two types (110) [100] and (100) [110]. The different crystallographic structures have different anisotropy of magnetic properties. In structures of the type (100) [110], the best properties are obtained by magnetizing the steel at an angle of 30–45° to the direction of rolling.

Regarding the 'two Curie points' of the Fe–Al alloys Sh. I. Zusman (*Fiz. Met. Metalloved.*, 1960, (4), 635–637) This is an examination of the paper by Sykes and Evans (*JISI*, 1935, **31**, 225), the findings of which regarding two Curie points and the cessation of ferromagnetism within the temp. range of the experiments are refuted.

Rapid identification of alloy and special steels by electrotesting L. Guitton (*Acciaio Inossid.*, 1958, **25**, (6), 199–201) This note describes the electrotesting method and its advantages in identifying rapidly and easily the various elements contained in alloy and special steels, particularly when electromagnetic and spectrographic methods cannot be used. In the electrotest, less corrosive reagents and a large number of different compositions can be used. Advantages are—low cost—the test piece sample is not altered—it can be used on finished equipment so long as a small part of its surface is flat and horizontal—immediate results are given showing the various elements and their characteristic colours

Electrical conduction in solids. III. The contact of iron surfaces J. A. Greenwood and J. Harris (*Proc. Roy. Soc.*, 1960, **257**, Aug. 23, 83–97).

Thermal and electrical properties of Armco iron at high temperatures M. J. Laubitz (*Canad. J. Phys.*, 1960, **38**, July, 887–907) Conductivities, thermoelectric power against Pt and thermal expansion were measured in the range 0–1 000°C. All show a discontinuity at the α–γ transition and a change of slope at the Curie point.

The electrical resistance of iron–aluminium alloys and its dependence on crystallographic order R. W. Cahn and R. Feder (*Phil. Mag.*, 1960, **5**, May, 451–465) Electrical resistance of two Fe–Al alloys (Fe_3Al) was measured. By analysis based on values of residual resistivity and temp. coefficient of resistivity the influence of order on electronic factors in the conductivity and in the perturbations of the lattice that produce scattering was estimated. Freedom of conduction electrons diminished as the order increased and the decrease in low temp. resistivity was due to reduced scattering potential, permitting a qualitative interpretation of the form of the anomalous resistance/temp. solution at high temp. (32 refs).—S. H.-S.

Improving the electromagnetic properties of transformer steel N. V. Keis and A. I. Komiesarov (*Stal'*, 1960, (8), 721) A note from Cholyabinsk. Oxygen blowing practice has been improved with removal of inclusions by the use of Si–Mg or Fe–Co.

Dependence of hysteresis and eddy current losses of electrotechnical steels on temperature V. V. Druzhinin and N. I. Mokrushina (*Fiz. Met. Metalloved.*, 1960, (4), 498–502) In dynamo steel (1·0–1·2%Si) when the temp. is increased to 250°, with an induction maximum of $B_{max} = 10000$ Gauss and f = 50 c/s, the decrease in the hysteresis losses amounts to 10–15% and eddy current losses to 25–35%. Between room temp. and −80° the increase in both these losses is slightly greater (by a factor of 1·3–1·5) than at 120°.

Testing electrical sheet W. P. Crawley (*Elect. Times*, 1960, **138**, Sept. 8, 339–341) Equipment developed for measurements of B–H curves and hysteresis loops is described including the NPL permeameter.

Effect of inclusions on arcing behaviour of metals P. C. L. Pfeil and L. B. Griffiths (*J. Nucl. Mat.*, 1959, **1**, Oct., 244–248) Certain types of inclusions having a comparatively high electrical resistivity cause arc initiation in stainless steels and in copper, and there is no apparent reason why other metals should not be similarly affected. A correlation is established between the resistivity of inclusions and their effectiveness as arc initiators.—S. H.-S.

Evaluation of surface defects on non-destructive testing W. A. Black (*AISI Reg. Techn. Meetings*, 1959, 123–144) A survey, from the viewpoint of the inspector, of methods of replacing visual inspection of surface defects by ultrasonic and eddy current methods with practical examples of their application and a brief summary of advantages.

The use of ultrasonic devices in heavy industry C. Bordoni (*Ing. Met.*, 1960, **9**, July, 57–68) After briefly outlining the principles of non-destructive ultrasonic testing, the article emphasizes the advantages of this method of testing welds compared with X-ray methods. The specific applications of ultrasonic testing—checking the depth of fatigue cracks, detection of material failures of all kinds by the absorption method, checking adherence of anti-friction metal to the bearing support, and testing grain dimension in special austenitic alloys are described.

Ultrasonic testing of chilled cast iron S. Wadewitz and A. Müller (*Giessereitech.*, 1960, **6**, July, 196–199) The principles of ultrasonic testing are explained and some results are reported on tests of chilled cast iron. If the test-pieces have parallel walls quite good results with respect to the depth of the chill zone were obtained, but when it came to rolls the tests were not satisfactory.—T. G.

Most favourable conditions for non-destructive assay of hot castings by ultrasonic methods: interpretation and comparison of results J. Ors Martinez (*Hierro y Acero*, 1960, **13**, Jan.–March, 268–275) A series of 11 oscillograms is presented, showing results of tests of castings under different conditions, and giving frequency of test, constriction of impulse, and amplification. The results are compared and the most favourable conditions of testing are determined.—S. H.-S.

Recent developments in the ultrasonic inspection of thin metallic sheet or plate R. Wilson (*Sheet & Strip Metal Users' Techn. Assoc. Annual Proc.*, 1951–1952, **5**, 19–35) A new method of testing thin sheet or plate is described in some detail.

Some defects in sheets and their harmfulness in relation to ultrasonic control E. de Kerversau (*Centre Doc. Sidér. Circ.*, 1959, **16**, (11), 2437–2444) The increased use of ultrasonic testing by steel consumers poses problems in establishing criteria for the rejection of sheets. Some examples are discussed together with the changes in fabrication techniques which will be necessary.—A. G.

Ultrasonic testing of heavy steel forgings (1st report, reflection from simulated discontinuity in water) A. Takaoki (*Bull. JSME*, 1959, **2**, May, 252–257) Data accumulated from tests with a Sperry Reflectoscope in a water tank of 900 mm dia. upon (1) infinite cylindrical, (2) finite cylindrical, (3) discal, and (4) spherical models are presented and the results compared and discussed. Equivalent reflection surfaces of each of three simulated discontinuities and bottom surfaces were investigated, and nomograms for size of discontinuities ϕ from γ and χ were established. While not immediately applicable for heavy steel forgings, the findings are advanced as help for the analysis of reflection phenomena and the arrangement of inspection data.

Internal defects of semi-killed steel plates T. Ohtake, K. Aoki, H. Gondoh, and Y. Sasaki (*Tetsu to Hagane*, 1960, **46**, Jan., 29–34) Defects were investigated by an ultrasonic method. Their extent is low for the first and last poured ingots, but high for those in between. It increases with pouring temp. It is reduced by inverse charging in the soaking pit. It is increased by excessive cropping. Short track times increase the defects. The defects are attributed to scum remaining near the top surface of the ingot.—K. E. J.

Use of reference blocks for checking ultrasonic inspection apparatus International Institute of Welding, Commission V (*Brit. Weld. J.*, 1960, **7**, April, 230–237) The results of independent examinations of the British and Dutch reference blocks, carried out by Belgian, Danish, French, and Swiss workers, are presented. Directions for use of the two blocks are given in appendices.

The attenuation of X-rays in the wave-length range $\lambda = 0{\cdot}01$–$10{\cdot}0$m μ E. A. Müller (**Siemens Messtechnik*, 1956, Feb., 37–38; May, 107–110) The extinction law and the processes of scattering and absorption are outlined and values are given for attenaution coefficients from element 3 (Li) to 92 (U) and graphically for some of the lighter elements in addition, as well as for compounds of Fe, ferrites, and other oxides and nitrides.

Evaluation and assessment of the X-ray and gamma film photography of castings E. Schiebold and E. Becker (*Giessereitechn.*, 1960, **6**, (3), 74–76) The detection and evaluation of defects by radiographic methods is discussed with particular reference to American methods.

X-Ray examination of the surface layer when grinding low-heat tempered eutectoid steel L. I. Mirkin (*Fiz. Met. Metalloved.*, 1960, (3), 459–460) Specimens of U8 (0·8%C) eutectoid steel were quenched from 800° and tempered for 1·5 h at 180°. These were ground with a longitudinal feed at a rate of 15–30 m/min and a transverse displacement of 0·01–0·05 mm. The results of the investigation show that the ratio of lines (110) and (220) of the α-phase was in all cases smaller than that of the sec of the angles of slip; i.e. the second

order of distortions does not play any appreciable role on the broadening of the lines. With the appearance of the austenitic structure, during the grinding of quenched high-carbon steels, therefore, the fine crystalline structure of austenite and ferrite in the surface layers changes in a similar way.

X-Ray analysis of iron and steel surfaces after diffusion-chromiding with powders N. V. Karyakina and G. N. Dubinin (*Fiz. Met. Metalloved.*, 1960, (6), 832–841) The findings of experiments here described are that nitrogen diffuses in the surface layers of iron and steel during chromiding with powders with the formation, on the iron surface, of chromium nitride (Cr_2N) and on the steel surface of a chromium carbonitride ($Cr_2(N.C.)$).

X-Ray and spectral analysis of the interatomic bonds in iron–aluminium alloys S. A. Nemnonov, L. D. Finkel'shtein, and K. M. Kolobova (*Fiz. Met. Metalloved.*, 1960, (2), 243–247) The increase in the electrical resistance in Fe–Al alloys, annealed between 200 and 400° after quenching from 800° was ascribed by earlier investigators to the formation of the K-condition. The authors, on the strength of their findings have proposed an explanation based on the different atomic charges in the Fe and Al ions. Further investigations are needed however in view of the difficulty of interpreting the Debye temp. as a measure of the interatomic bonds in solid solutions.

X-Ray analysis of phase recrystallisation when heating steel A. K. Varskaya, N. A. Kompaneitsev, B. K. Sokolov, and V. D. Sadovskii (*Fiz. Met. Metalloved.*, 1960, (1), 28–30) X-Ray examination has shown that with very rapid or very slow heating the texture of the secondary martensite repeats its initial texture, which disappears finally only with overheating during recrystallization of the austenite conditioned by phase hardening.

Radiographic investigation of the structure of metals in the liquid state E. Z. Spektor (**Principes Physico-Chimiques de l'Elaboration de l'Acier*, pp.257–262) [In French] The determination of distances between neighbouring atoms in a liquid, and conclusions to be drawn regarding interacting forces between atoms and molecules are reviewed. Some nonferrous examples are discussed.

The quality control of welds by radiographic inspection G. J. Janssen (*Metalen*, 1960, **15**, June 15, 182–187) It is pointed out that for correct assessment of the results of a radiographic examination one should possess all the necessary data and also employ the proper technique. The latter involves the source of irradiation, the film and intensifying screens, the influence of these latter on the former and then the scattering of the rays between the test piece and the surroundings. The influence of the geometrical shape of the test piece is also discussed. The first instalment summarizes the most important points and the second puts forward two procedures on which the quality control may be based.—F. R. H.

Technique for non-destructive electron micrography and microfractography. Applications to the examination of massive parts A. Jacquet and E. Mencarelli (*Rev. Mét. Mém. Sci.*, 1960, **57**, April, 241–253) Using the technique previously described by the author, employing local electrolytic polishing and nitrocellulose varnish replicas, it is shown that the method can be extended to electron microscopy by making use of the carbon imprint formed on the replica. A number of examples are given of the application of the method to the examination of parts which had failed in service (19 refs).

Use of radioisotopes in metallurgy and metal physics I. S. Kulikow (*Neue Hütte*, 1960, **5**, June, 348–354; July, 420–425) A review of the literature dealing with the use of radioisotopes in studying the theory and practice of metallurgical processes, investigations on metallurgical plants, distribution and segregation of elements in metals and alloys, of diffusion and autodiffusion in solids, and quality control of metallurgical processes (317 refs).

Materials for service above 1000°F: Metals and ceramics J. J. Harwood (*Mech. Eng.*, 1959, **81**, Oct., 46–51) A review with properties of the high-strength steels.

Effect of alloying on the hardening and softening of high-temperature iron-base alloys D. F. Zhirnov (*Metallov. Term. Obra. Met.*, 1959, (3), 17–19) Working with a base composition of 13%Cr, 8%Ni, and 8%Mn, the effects of C, V, Al, Mo, W, and Nb were studied.

Mechanical properties of strain-hardened 18–8 type steels at subzero temperatures N. N. Lyulicheva and N. V. Pisareva (*Nauchn. Doklady Vyssh. Shkoly, Metall.*, 1959, (2), 217–220) Strain-hardening is recommended at room temp. for components for service at low temp. Working at subzero temp. does not require a preliminary quench.

Study on type 321 stainless steel intended for high-temperature service such as for superheater and reheater tubes. II. Study on structures and carbide changes observed in each specimen before and after creep rupture tests M. Nishihara, H. Hirano, S. Yamamoto, and K. Yoshida (*Tetsu to Hagane*, 1960, **46**, Jan., 39–53) Carbides pptd. in all specimens quenched from 1300–800° before the creep-rupture tests were identified as TiC and other carbides. The lattice constants varied with the quenching temp.

High-temperature properties of four low-alloy steels for jet-engine turbine wheels (*WADC* 53–277; *PB* 133856, Part II [no date], pp.121; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 121; no abstract).

The slow deformation of the monocrystals of the iron–nickel solid solution at high temperatures V. M. Rosenberg (*Fiz. Met. Metalloved.*, 1960, (6), 922–926) The specimens were prepared from an alloy containing 30%Ni; 0·4%Ti, 0·15%Mn and the remainder Fe. Such an alloy is a solid solution with a cubic face-centred lattice. On cooling the γ-solid solution below room temp. the γ–α martensite transformation takes place. Heating the transformed α-solid solution above 500° the reverse α–γ martensite transformation occurs. The experiments here reported justify the conclusion that the different behaviour of the annealed specimens undergoing phase hardening is not due to any qualitative change in the deformation mechanism. The presence of a defective lattice in the transformed specimens results in an intensification of slip, which is more intense than in the annealed specimens.

The properties of materials in the low temperature range of liquid gases W. Parpan (*Schweiz. Arch.*, 1960, **26**, June, 253–255) This is a discussion on a paper by L. Piatti, published in March 1960, The present author draws attention to a development carried out by the International Nickel Company of America on the ageing behaviour and mechanical strength of a 9%Ni steel at temp. of −196°C. Some uses of this steel are indicated.

The effect of a load applied to technical iron at 300°K, on its mechanical properties at 77°K I. A. Gindin (*Fiz. Met. Metalloved.*, 1960, (3), 447–455) The experiments have shown that technical iron first loaded at 300°K within the elastic region and then cooled, under load, to 77°K, passes at that temp. from the brittle to the plastic condition. This transition is accompanied by an increase in the true UTS in comparison with the brittle technical iron. It has also been shown that the initial stage of plastic deformation at 77°K of this iron when first treated at 300°K, proceeds until the upper yield point has been reached.

The dynamic effect of thermal energy applied to copper, aluminium and mild steel N. F. Kunin and L. I. Afanas'eva (*Fiz. Met. Metalloved.*, 1960, (1), 24–27) The residual thermal energy applied to Cu, mild steel, and Al, after static deformation has been measured. The specimens consisted of 1·5 mm dia. wires of these metals threaded through rubber tubes through which water at the desired temperature was flowing. Three tubes were used, through one of which water flowed at room temp.; the ends of the wires were then connected as required to a mirror galvanometer of 415Ω resistance and 0·08 μV sensitivity. The specimens were statically deformed. A considerable dynamic effect of the residual heat energy was observed. The dynamic coefficient of the applied heat energy falls, in all cases investigated, with an increase in the degree of deformation. This coefficient is greater the lower the m.p. of the metal.

The effect of quenching on the heat conductivity of carbon steels B. E. Neimark and V. E. Lyusternik (*Teploenergetika*, 1960, (5), 16–18) Quenching has little effect on the thermal conductivity of St 15 low carbon steel. However, with a carbon content exceeding 0·30% this effect becomes appreciable (especially for U8 steel). Due to the different effects of quenching on the thermal conductivity, heat capacity, and specific gravity, the properties of the quenched steels have a very complex relation to temp. Between 0 and 200° heat conductivity is less, and beyond 200° it is greater than in annealed steels. Between 500 and 900° the heat conductivities of annealed and quenched steels are equal.

Special features of the diffusion redistribution of carbon in super-cooled austenite L. S. Palatnik and I. A. Tananko (*Fiz. Met. Metalloved.*, 1960, (4), 554–557) The type of steel investigated was 18KhNV: with 0·32%C (32KhNV), with 0·70%C (70KhNV), and with 1·2%C (120KhNV). X-ray photographs were taken by the method previously described (*ibid.*, 1959, **7**, (6), 842). An examination of the photographs confirms that the diffusion redistribution of carbon proceeds at a rather high rate with the separation of the initially homogeneous austenite into two solid solutions characterized by different carbon contents. In the high carbon steel (120KhNV) the transformation proceeds in the γ-phase regions enriched with carbon while in the regions of smaller carbon content no decomposition is observed.

The migration of carbon in bimetals and welding joints of different types of steel I. N. Gerasimenko (*Fiz. Met. Metalloved.*, 1960, (4), 520–524) It is known that the solubility of carbon in γ-iron is appreciably greater than in α-iron and that because of the appreciable decrease in its activation energy, carbon migrates rapidly from the carburized zones of EI 496 and 12 MkH steels. Hence, by controlling the diffusion of carbon in welding joints of different steels, it is possible to improve the quality of the joints without using separating layers between the steels such as pure iron, nickel, or other metals impeding carbon migration.

The effect of silicon on the carbon diffusion in austenite M. A. Krishtal (*Fiz. Met. Metalloved.*, 1960, (2), 317–319) At low temp. Si speeds up carbon diffusion and at high temp. it slows it down, as it results from the investigation of the diffusion coefficient (through cm²/sec) and of the activation energy of specimens with different Si contents.

The diffusion of certain elements from a single source in iron and its alloys M. A. Krishtal (*Fiz. Met. Metalloved.*, 1960, (5), 680–688) The possibility of observing simultaneously the diffusion of a few elements from one source by local spectrographic analysis has been demonstrated by investigating the diffusion of Ti, Mn, Cr, Si, and Mo in iron and binary iron alloys each containing 5 atom %Co, Cr, Si, and V. The diffusion rate of the elements in iron and binary iron alloys increases in the order Ti, Mn, Cr, Si, Mo.

Studying the causes of the diffusion 'activity' of crystalline bodies with distortions. V. The causes of diffusion 'activity' of metals with non-uniformities in their macroscopic structure Ya. E. Geguzin (*Fiz. Met. Metalloved.*, 1960, (6), 842–851) The possible role of the excess 'atomic' vacancies in the increase of the diffusion 'activity' of metals may mean that the increase in the diffusion coefficient, established experimentally when sintering compacted powders, cannot be conditioned by an excess of 'atomic' vacancies. The role of the boundary network and of the spaces in metals with increased activity and with macrostructural non-uniformities has also been studied by computing the real diffusion coefficients in specimens with the simplest geometry, and the findings show that the boundary network may well cause a considerable increase in the real diffusion coefficients.

Influence of metal purity on the intergranular self-diffusion of iron in the α-phase C. Leymonie and P. Lacombe (*Rev. Mét. Mém. Sci.*, 1960, **57**, April, 285–290) The constants of grain boundary self-diffusion in the α-range in

high purity were determined, using the sectioning technique and Fisher's analysis. For 99·6–99·7% iron specimens the activation energy at 40 kcal/at-g is in good agreement with the results of previous experiments using a different method (*ibid.*, 1959, **56**, 74). Grain boundary self-diffusion was found to be slower in a purer iron (99·96%Fe) (21 refs).

Effect of silicon on magnesium diffusion in iron K. I. Vashchenko and N. A. Golovan' (*Lit. Proizv.*, 1960, (2), 27–28) With the saturation of the iron surface with Mg, carbon content falls due to a partial solution of the graphitic inclusions which assume a spheroidal character. Under a microscope this decarburization may be followed. The intermediate layer is then seen to contain an appreciable quantity of structurally free cementite while the core is almost entirely pearlitic. The graphite becomes spheroidal. Mg does not diffuse in pure iron, but in iron containing up to 2%Si diffusion may be noticed.

Contribution to the study of the diffusion and localisation of hydrogen in a dead-mild steel. Consequences for embrittlement J. Plusquellec (*Rev. Mét. Mém. Sci.*, 1960, **57**, March, 215–231) The diffusion coefficient of H_2 in a dead-mild steel is determined, using an electrolytic charging method, and it is shown by a radiocrystallographic investigation that H_2 is present on the (112) planes and in the defects associated with these families of planes. H_2 embrittlement in uniaxial tension is examined. (April, 265–277) In this section the influence of preliminary cold working on H_2 embrittlement is examined and the results interpreted, and the general process of H_2 embrittlement is considered. Embrittlement is explained by the momentary flow of protons brought about by dislocations which have accumulated in front of an obstacle (64 refs).

The solubility of hydrogen and nitrogen in liquid alloys of iron, nickel and cobalt T. Busch and R. A. Dodd (*Trans. Met. Soc. AIME*, 1960, **218**, June, 488–497) The solubility of hydrogen in pure iron and pure nickel and of nitrogen in pure iron has been determined and agrees well with earlier data. Nitrogen is insoluble in pure nickel and cobalt. The solubility of hydrogen in Fe–Ni alloys increases non-linearly with increase in nickel content but the solubility of hydrogen in Ni–Co and Fe–Co alloys reaches a minimum at 75 and 50 at-% respectively. The solubility of nitrogen in Fe–Co alloys decreases approximately linearly with increase in cobalt content. Nitrogen is insoluble in Ni–Co alloys. Determined interaction parameters are in good agreement with predictions of Goken and Ohtani.

Rupture strength of tubular steel specimens under internal hydrogen pressure at high temperature N. N. Kolgatin, L. A. Glikman, V. P. Teodorovich, and V. I. Deryabina (*Metallov. Term. Obra. Met.* 1959, (3), 19–24) The results of studies on iron, various low-alloy steels, a 13%Cr steel, and an 18/8 type steel are given.

The effect of hydrogen on steel in oil industry installations (*Acciaio Inossid.*, 1960, **27**, (1), 373–382) This article describes the behaviour of steel due to H_2 during the processing of mineral oils. Advice is given on the appropriate steels to be used for high temp. refinery uses. The first part deals with the action of H_2 at ordinary temp. when it originates as atomic H from aqueous solutions in contact with steel. The second part deals with H_2 attack at high temp. with special reference to catalytic reforming plants in which it is noted that H_2 in the gaseous state and under pressure constitutes practically all the fluid which comes into contact with the steel. Reference is made to the literature on the best materials for limiting the attack of the harmful element contained in the hot reforming gases.

Present-day knowledge of the properties of steels which are resistant to the action of pressurized, hot hydrogen gas I. Class (*Stahl Eisen*, 1960, **80**, Aug. 18, 1117–1135) For chemical-plant construction steels are often required that can withstand the attack of H_2 at temp. up to 600°C and pressures up to 1000 atm. As the H_2 acts mainly as a decarburizer the steels resisting such an attack must contain stable carbides and steels of this type are alloyed with Cr–Mo, or Cr–Mo–V–W. In the austenitic type of steels the 15:15 Cr–Ni composition with stabilizing additions of Nb and Ta are used. In these steels the Mo content is kept very low, whereas small additions of V and W increase the strength.—T.G.

The escape of hydrogen from iron H. B. Wahlin and D. J. Mack (*Acta Met.*, 1959, **7**, Oct., 687–689) A letter. The rate of escape of H_2 from Armco iron was assessed by noting the decrease in brittleness by a torsion method. The diffusion rate of H_2 is considered to be governed by the probability of H-atoms recombining to form molecules.—A.G.

Gases in metals, escape of hydrogen from plates of plain carbon steels M. Goldman (*WAL 833/5; PB 127556*, 1951, Oct., pp.55; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 122; no abstract).

On the function of nitrogen as an alloying element in heat-resisting materials. VI. On the high temperature nitrogen absorption of nitrogen-bearing 20%Cr–Fe alloys in pure nitrogen M. Okamoto and O. Miyakawa (*Tetsu to Hagane*, 1960, **46**, Feb., 157–162) The depth of the austenite zone formed at the surface by N_2 absorption at 1250°C was determined for alloys of varying N_2 content. The austenite decomposed to ferrite and Cr_2N during furnace cooling, and the ferrite–austenite change on heating occurred at 900–1050°C. Retained austenite was susceptible to subzero treatment, and stabilization at room temp. was not pronounced (11 refs).—K.E.J.

The solubility of carbon in alpha-Fe as determined by the time decay of permeability J. Singer and E. S. Anolick *Trans. Met. Soc. AIME*, 1960, **218**, June, 405–408) The magnetic after-effect in the form of time decay of permeability ($\Delta\ 1/\mu$), has been used to obtain independent data on the solubility of carbon in pure iron. The results differ slightly from the solubilities obtained through internal friction experiments. The mechanism of the time decay is the magnetic analogue of internal friction and some suggestions are made to explain the observed discrepancies.

Addition of small amounts of cobalt to steel L. Harbraken (*Rev. Mét.*, 1960, **57**, May, 445–450) The effects on steel properties of low Co contents (up to 5%) are studied in a low-C rimming steel, on low-alloy steels, and on 13%Cr steel. Additions of a few tenths % have a pronounced effect on both hot and cold ductility (17 refs).

Effect of certain less-common alloying elements on the mechanical properties of iron–aluminium alloys E. M. Savitskii, V. F. Terekhova, and I. V. Burov (*Metallov. Term. Obra. Met.*, 1959, (3), 38–43) Studies on Zr, Ti, Ta, Nb, V, B, Mo, and Co are reported, 38 compositions are tabulated. Magnetic and other measurements are included.

The effect of arsenic on carbon and alloy structural steels M. I. Kurmanov and T. F. Filippova (*Stal'*, 1960, (7), 637–642) A streaked structure is demonstrated in As-containing steels. A number of experimental melts were made in an induction furnace and it was shown that up to 0·3%As has little effect on mechanical properties though certain effects are shown. Nitriding is impeded and temper brittleness is increased.

New steels: high-nickel system and a modified alloy (*Met. Prog.*, 1960, **77**, Feb., 66) A new series of nickel alloy steels reported by International Nickel Co. contain 20–30%Ni, and have given yield strengths of over 290 000 psi by air cooling from heat treatment temp. 2–6%Ti or Al or a combination of the two are also added. A description is also given of the properties of 'Strux' low alloy, a steel developed by United States Steel Corp., and giving tensile strengths of 280 000–300 000 psi after quenching and tempering.

A nitriding steel that age hardens W. S. Mounce and A. J. Miller (*Met. Prog.*, 1960, **77**, Feb., 91–94) The steel described contains 5%Ni and 2%Al, and is nitrided and hardened simultaneously by ageing at 950–1100°F in a nitriding atmosphere. A minimum tensile strength of 200 000 psi is obtained.

Die forging steel type 5KhGS V. I. Zalesskii, D. M. Korneev, Ya. M. Okhrimenko, and I. N. Laguntsov (*Vestnik Mashin.*, 1960, (4), 50–54) The chemical composition of the steel was 0·45–0·55%C; 1·6–2·0%Cr; 0·9–1·1%Mn; 1·2–1·4%Si; and S and P 0·04% maximum each. The average critical points were Ac_1 780°C; Ac_3 800°; Ar_1 700°; Ar_3 740°. Indices of physical properties are given for different temp. of thermal treatment.

New types of stainless steel (*Acciaio Inossid.*, 1959, **26**, (1), 13–14) The Avesta steelworks has recently extended its range of production by adding new types of stainless steels with a new and increasing resistance to certain types of corrosion, by increasing the Ni content of 832 8K steel from 11 to 14%. Tables are given showing the mechanical and physical properties of the steels and their uses. A new steel standard AISI D319 for the control of pressure containers is described, which differs from AISI 316 by its higher Mo content.

Special corrosion and heat resisting steels. U.N.I. tables 4047 (*Acciaio Inossid.*, 1959, **26**, (2), 53–57) This is a reproduction of the new Italian UNI standard tables for stainless steels resistant to corrosion and heat intended for cold or hot working.

Design and fabrication properties of high-strength steels A. M. Hall (*Mach. Design*, 1960, **32**, July 21, 174–176, 179, 180) Low-alloy hardenable, Cr hot-work die, martensitic stainless, semi-austenitic stainless, and cold-rolled austenitic stainless steels are reviewed and creep and short-time elevated temp. strengths are shown. Welding properties are noted.

Possibilities of tungsten-alloyed constructional steels in the 'very high strength' field J. A. Garcia Poggio (*Inst. Hierro Acero*, 1960, **67**, May, 536–570; *Special Number*) A series of alloy steels containing W has been investigated with a view to use in the high strength field as substitutes for the conventional Mo steels. The steels were Mn–W (0·34%C, 0·42%Si, 1·22% Mn, 0·87%W), Cr–W (0·26%C, 0·38%Si, 0·52%Mn, 1·10%Cr, 0·54%W, and 0·33%C, 0·49%Si, 0·54%Mn, 1·35%Cr, 0·69%W), and Mn–Cr–W (0·24%C, 0·46%Si, 1·26%Mn, 1·16%Cr, 0·55%W) types and a similar series but with a higher Si content (about 1·5%). The critical points, susceptibility to grain growth, hardenabilities, property charts, isothermal transformation diagrams, and fields of use for each steel have been determined and the data are included in the report. A comparison of the Cr–W steel (0·33%C, 1·35%Cr, 0·69%W with a Cr–Mo steel (0·33%C, 1·24%Cr, 0·30%Mo) is also included. It is concluded that these steels are similar in behaviour to, and may be substituted for, the conventional Mo steels; this result can have an important effect on the national economy (29 refs).

When to use Avesta 832T or Avesta 832 MVT steel (*Acciaio Inossid.*, 1959, **26**, (3), 102–103) This is an explanatory note prepared by Avesta steelworks comparing the applications of the Avesta 832T heat resistant steel with the Avesta 832 MVT corrosion resistant steel.

Comparison between analyses of Avesta stainless steels and those prescribed by certain Italian and foreign standards (*Acciaio Inossid.*, 1959, **26**, (3), 104–106) To aid consumers in their choice of Avesta steels these are compared in analysis tables with Swedish, British, American, and Italian standards—with brief explanatory notes.

Comparative effectiveness of weld inspection with various radioisotopes A. S. Fal'kovich and I. E. Neifel'd (**Svar. Proizv.*, 1956, (9), 23–24) Tests with ^{134}Ca, ^{192}Ir, ^{137}Cs and ^{154}Eu as replacements for ^{60}Co were made for pipeline weld inspection and other oil industry structures. The value of sealed high-intensity sources is discussed and recommendations for the use of ^{134}Ca are made. All the isotopes can be used but the cost of ^{154}Eu and ^{137}Cs is at present high.

Steel and refractory alloys (*Técn. e Ind.*, 1960, **38**, April, 497–501) A short summary of the principal refractory alloys, their properties and uses.

High-temperature stainless steels—the 'Jethete' series (*Iron Steel*, 1960, **33**, Mar., 114) A description of the properties of a series of

special alloy steels developed by Samuel Fox and Co. Ltd, for use in the aircraft industry and such applications as the low-pressure turbine blades in power stations.

METALLOGRAPHY

Emission microscopy by ion-excited electrons H. Düker (*Schweiz. Arch.*, 1960, **26**, May, 199–201) An electron-emission microscope is described for the direct observation of metal surfaces at 20–1100°C. The electrons are emitted from the surface of the object to be studied by bombardment with ions. The resolution is temp.-independent and is in the region of ~500 Å. In the present apparatus, magnifications of 550, 1150, and 1600 may be selected. Ion etching and surface reactions can be carried out with various gases. This microscope is particularly suited for the study of transformations, precipitation, and recrystallization processes.—T.G.

Study on ferrous materials with the electron microscope. II T. Akutagawa and I. Uchiyama (*Tetsu to Hagane*, 1960, **46**, Feb., 163–172) A review (72 refs).—K.E.J.

From the work of the electron microscopy laboratory of the Bergakademie Freiberg P. Dietzmann (*Bergakademie*, 1960, **12**, May–June, 294–298) Most of the examples are non-ferrous, but examinations of the fractured surfaces of steel specimens are reported, and micrographs are reproduced.

Direct determination of the mean particle size of microscopical sections with the aid of the electric point counting apparatus equipped with a micrometer eyepiece G. Schneider (*Z. Metallk.*, 1960, **51**, July, 414–420) The Eltinor point counter for microscopical particle size measurement is described and a number of examples quoted in which particle size measurement and qualitative and quantitative particle size classification by integrating is carried out simultaneously for one or more components in one single operation.—T.G.

Etching method for use with Fe–Ni alloys W. D. Hannibal (*Acta Met.*, 1959, **7**, Oct., 697–699) [In German] A letter. The 50–50 alloy is especially considered. Optical and electron photographs are shown. Electrolytic etching is used with chromic-acetic or a proprietary solution, or a mixture of these.

A simple electropolishing cell M. K. Asundi and K. Tangri (*Metallurgia*, 1960, **61**, March, 139–140) The cell is described, and examples of work done with it are given. The advantages claimed are (1) only a small quantity of electrolyte is required; (2) change-over of cathodes and electrolytes is easy; (3) the system is highly resistant to corrosive electrolytes; (4) despite its simplicity, the unit gives satisfactory results.

Observations on the thermal etching of silicon–iron D. S. Hutton and W. C. Leslie (*Trans. Met. Soc. AIME*, 1960, **218**, June, 525–533) Thermal etch patterns developed on polycrystalline 3·5%Si–Fe by heating in hydrogen or in argon have been examined. The most prominent feature of the etching is the development of striations on grains with (100) planes near the plane of the surface. These striations are probably produced by the resolution of a random high energy plane into (100) facets of lower energy.

An iron–silicon carbide J. G. Humphreys and W. S. Owen (*Nature*, 1960, **187**, Aug. 13, 589–590) A letter. The findings are to be published in full later.

Nitrides of iron with nickel, palladium and platinum H. M. Stadelmaker and A. C. Fraker (*Trans. Met. Soc. AIME*, 1960, **218**, June, 571) Earlier research reported the existence of the nitrides Fe_3NiN and Fe_3PtN with a cubic $L1_2$ structure. This note shows that a similar nitride can be observed and that the composition range between the iron nitride Fe_4N and the nitrided Ve_3NiN, Fe_3PdN, and Fe_3PtN is occupied by single phase cubic nitrides with structures intermediate between $L1'$ and $L1_2'$.

Contribution to the study of the solidification of alloys A. Kohn and J. Philibert (*Rev. Mét. Mém. Sci.*, 1960, **57**, April, 291–312) The article deals mainly with non-ferrous alloys, but includes a section describing tests on various ferrous alloys with the Castaing microsonde, in which the dendritic structure is analysed. Curves are presented showing the concentration of alloy constituent as a function of inter-dendritic distance, obtained during slow cooling (30 refs).

Influence of the purity of iron on its susceptibility to polygonisation after severe hardening J. Talbot (*Compt. Rend.*, 1960, **231** July 11, 243–245) The effects of tests on different samples of iron, including 'Armco' and electrolytic irons are described.—S.H.-S.

Band structure in type 10 C6 steels and more generally in hypereutectoid tool steels Sellier (*Centre Doc. Sidér. Circ.*, 1959, **16**, (8), 1795–1799) The harmful effects of band structure, associated with the segregation of Cr carbides are described. The factors in the method of production, casting practice, and subsequent working, which affect the formation of these bands are considered.—A.G.

Microtwinning in epitaxial nickel–iron films R. D. Burbank and R. D. Heidenreich (*Phil. Mag.*, 1960, **5**, April, 373–382) Thin films of Permalloy (81%Ni, 19%Fe) have been studied by electron microscope, and diffraction patterns indicate microtwinning on all types of {111} planes, being subject to effects of multiple diffraction and film deformation, and a film is revealed which consists of discrete three-dimensional particles which are a consequence of isotropic growth of crystal nuclei. Microtwinning seems to be a relief mechanism for reduction of strain energies which accumulate at the boundaries between growing crystal nuclei.—S.H.-S.

Nature of the matrix for secondary recrystallization to the cube texture in high purity silicon iron C. G. Dunn and J. L. Walter (*Trans. Met. Soc. AIME*, 1960, **218**, June, 448–453) The characteristics of cube-oriented nuclei and other matrix grains associated with secondary recrystallization were investigated by metallographic and X-ray methods. The results show that the structure consists of relatively perfect grains of average diameter between one and two times the sheet thickness and that the texture has a moderately strong (110) [001] component and a weak (100) [001] component.

On the Widmanstätten habit plane of proeutectoid cementite R. W. Heckel, J. H. Smith, and H. W. Paxton (*Trans. Met. AIME*, 1960, **218**, June, 566–568) The habit plane of proeutectoid cementite precipitated from austenite was studied using a two-trace surface analysis coupled with a direct X-ray back-reflection determination of the orientation of the parent matrix. The results were the same as those obtained by earlier workers using indirect methods. The data indicate that a range of habit planes in the parent phase is operative which is not in agreement with accepted theories.

Influence of deformation and deformation rate on the recrystallization of ferrite 25%Cr steel after hot plastic deformation C. Rossard and P. Blain (*Rev. Mét. Mém. Sci.*, 1960, **57**, March, 173–178) The structure obtained by changes due to hot working followed by holding at temp. is examined. It is found that there is a deformation threshold above which recrystallization occurs, after an incubation period varying with amount and rate of deformation and temp.

Grain size in high-alloy hot work toolsteels R. F. Harvey (*Met. Prog.*, 1960, **77**, Feb., 109–111) The isothermal technique used for delineating grain boundaries in these steels is described (Payson and Nehrenburg: *AISI Yearbook*, 1948, 540), and it is shown that W inhibits grain growth, and rehardening treatments produce duplex structures.

A time-temperature relationship for recrystallization and grain growth F. R. Larson and J. Salmas (*WALR* 805/30; *PB* 128094, 1953, April, pp.57; from *US Govt. Res. Rep.*, 1960, **33**, Supplement; April, 123; no abstract).

The recrystallization texture of cold-rolled electrical steel I. P. Kudryavtsev (*Fiz. Met. Metalloved.*, 1960, (6), 939–940) This is an addendum to the article by Drushinin and Kudryavtsev which appeared in the *Stal'* supplement for 1958, p.88, on metal physics and heat treatment.

Microscopical determination of the decarburization of tool steels Yu. A. Geller and M. N. Fadyushina (*Zavods. Lab.*, 1960, (3), 307–310) A few relevant methods are considered. The one proposed by Popov and Michalev (*ibid.* 1955, (4)) was checked against the method proposed by Sadovskii (*idem.*, 1934, (6)) and also by chemical analysis of the layers. All methods give very similar results but chemical analysis by layer shows a slightly greater decarburisation depth.

A method of continuous microscopical observation of the surface during electrolytic treatment V. I. Shevchenko and E. N. Alpatov (*Zavods. Lab.*, 1960, (1), 77–78) An apparatus is described in which 10×10×40 mm specimens can be immersed in an electrolyte under a microscope with a special attachment which gives a ×400 magnification. This apparatus has also a few other laboratory uses.

Electron analysis of carbide formation in alloy steels S. S. D'yachenko, I. A. Vasis, and N. A. Kharchenko (*Fiz. Met. Metalloved.*, 1960, (3), 441–446) Investigations have shown that in the 20KhM steel, the carbide Fe_3Mo_3C forms directly from the austenite at 700°. This is recorded on the electron micrographs after keeping 1 min at that temp. The precipitated particles are very small, ~10^{-7} cm. A keeping period of 30 min results in the formation of $Cr_{23}C_6$ carbide in addition to the carbide first mentioned. A further holding for up to 10 h produces no changes in the composition of the carbides. Similar results were obtained with 15Kh1M1F steel.

Instrument for electrolytic polishing and etching of microsections directly on the component N. N. Popova and V. A. Malyshenko (*Zavods. Lab.*, 1960, (3), 367–368) The apparatus has a device for continuous circulation of the electrolyte during the process and this improves the transition zone between the polished and the original surface, which remains almost flat. It also has a device for preventing the electrolyte from leaking out on to the component on removing the attachment so that etching and polishing may be carried out from any angle. Diagrams are supplied.

A new reagent for metallographic microsections V. Ya. Savenkov (*Zavods. Lab.*, 1960, (3), 371–372) The alcoholic solutions of nitric and picric acids used in most cases have the disadvantage of forming colloidal films of corrosion products, soluble with difficulty, and impeding observation at magnifications of ×1000 and more. Chloride salt solutions are very suitable for the purpose since their corrosion products can be easily removed. A weak acidity furthermore does not decompose the carbides. A suitable reagent, successfully tested, is a mixture of three parts of a 10% aqueous solution of chlormmine-T with one part of a 10% aqueous solution of citric acid.

Contribution to the study of the extraction and analysis of non-metallic contents in carbon steels E. Penna (*Bol. Ass. Bras. Met.*, 1960, **16**, April, 387–399) The processes of extraction of the contents of oxides in steel, principally in anodic dissolution, are described; and the treatment of the primary residue of electrolytic extraction, having in view the elimination of carbonate, by the subsequent analysis of the residue obtained, is discussed.

The carbide constitution and tempering behaviour of chromium–vanadium–niobium steels at 700°C K. C. Mills, B. B. Argent, and A. G. Quarrell (*JISI*, 1961, **197**, Jan., 9–21) [This issue].

Summing up the contradictions regarding the carbide phases forming when tempering carbon steel B. A. Apaev (*Fiz. Met. Metalloved.*, 1960, (3), 400–414) A survey of the various methods available for analysing these phenomena is given. Magnetic analysis based on strict physical principles is as effective as X-ray analysis. Both permit qualitative and quantitative determinations of the phases. Magnetic analysis confirms the formation of 3 carbide phases: FeC; χ-Fe_5C and Fe_3C, with Curie points respectively 210, 265 and 380° but does not confirm the authors conception of the formation of a number of isomorphic hexagonal and cementite structures which are incompatible with the formation of only three carbides. The ferromagnetic theory together with some experimental data do not show the

existence of a connection between the discontinuity of the curves of magnetic saturation in the region of 265° and the displacement of the Curie points of cementite under the action of an applied load.

Metallographic control of steel from non-metallic inclusions M. S. Mikhalev and L. V. Mironov (*Stal'*, 1960, (7), 647–649) Examination of steel batches rejected on the basis of a test for inclusions described previously has shown that a much greater number of micro-sections must be examined for the process to be reliable. A long series of studies on rimming steels shows that average figures are not satisfactory for inspection and a discussion on probability theory is given. It is proposed that careful attention should be given to the melting process with only occasional examination for inclusions over a period and without attempting to examine every batch.

Analysis of extracted residues by an X-ray fluorescent method H. Hughes and L. Gwilliam (*Metallurgia*, 1960, **61**, May, 231–234) A method is described for the X-ray fluorescent analysis of small amounts in the order of 0·1 g of residues extracted electrolytically from alloy steels. The method is not limited to extracted residues but may be used for any material in powder form, such as oxide scales, corrosion products, etc. In view of the small amount of sample used the results are considered to be very good.—T.G.

The distribution of molybdenum and tungsten between the solid solution and the carbide phases of alloy steels N. F. Lashko and N. M. Popova (*Stal'*, 1960, (7), 642–644) The carbides were isolated by electrolytic solution and analysis of these showed Mo to be a more powerful carbide former than W, as the Mo : W ratio is higher than that in the steels. The thermal stability of the carbides is increased by Mo.

Micro-zonal carbide analysis on the fracture surfaces of molybdenum steels L. V. Zaslavskaya and N. N. Popova (*Zavods. Lab.*, 1960, (2), 135–137) Crack formation and failures of metals occur in many cases at grain boundaries enriched with alloy elements and containing increased amounts of carbide. To study the origin of the enrichment, phase analysis of the surface layer of the fractured surfaces is necessary. An electrolytic method is described for this purpose consisting of two stages: the specimen is first immersed in the electrolyte after having been coated with a resin leaving only the fractured surface free. The deposits from the cathode are dissolved in HCl. The specimen is then cleaned and again electrolytically analysed for Mo carbides. Almost the whole of the Mo introduced into the steel was found in the form of carbides in the fracture zone.

The origin of the excess phases in stainless chromium–nickel–molybdenum–niobium steel N. P. Agapova, F. P. Butra, and S. N. Votinov (*Fiz. Met. Metalloved.*, 1960, (3), 422–425) X-Ray analysis has established the fact that the electrolytic deposit of the excess phases in specimens quenched from 1200° and above, consists predominantly of niobium carbide. On reducing the temp the relative amounts of carbide in the precipitates decreases and the quantity of intermetallic compounds increases, $(MoNb)Fe_2$. The migration of the alloy elements from the dispersive phases into the solid solution at these temp is accompanied by a reduction in hardness and an increase in the electrical resistance and impact strength.

An electron microscopical investigation of the tempering of 18–4–1 high-speed steel C. H. White and R. W. K. Honeycombe (*JISI*, 1961, **197**, Jan., 21–28) [This issue].

Cinematographic recording of transformations and oxide formation on iron in the electron-emission microscope H. Düker (*Z. Metallk.*, 1960, **51**, July, 377–381) The technique of filming transformation phenomena and oxide film growth in the electron-emission microscope, in which the electrons are emitted as a result of ion bombardment of the object, is described and pictures are shown of transformation in a 0·45%C steel and of the oxide formation on Armco iron.—T.G.

Determination of the transformation points of steels by means of differential dilatometry A. Kohn (*Centre Doc. Sidér. Circ.*, 1959, (8), 1819–1835) Results are reported of a survey of dilatometric techniques and the interpretation of the curves obtained, with the object of reducing the divergency between laboratories. A method of determining the transformation point is proposed which should be reproducible to ±10°C.—A.G.

Physico-chemical investigation of the modifications of cementite produced by the dissolution of silicon and molybdenum B. Oudoit (*Rev. Mét. Mém. Sci.*, 1960, **57**, March, 194–202) It is shown that pure cementite can be obtained by the action of a mixture of CO and H_2 containing 12%CO on iron oxide at 550°C. The properties of Si-containing cementite are examined by carburizing FeSi with hydrocarbons; the Curie point is reduced, but the amount of Si dissolved is small. Cementites containing substituted Mo were obtained by heating mixtures of Fe_3C and Mo in vacuum; solubility of Mo varies with temperature, and reduces the Curie point of cementite considerably (35 refs).

Relationship between isothermal and anisothermal nucleation characteristics of austenite decomposition products C. R. Simcoe and A. R. Elsea (*WADC TR–54–330; PB* 130378, 1954, Sept., pp.34; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 124; no abstract).

On the properties of nickel austenites P. Geudrel and L. Jacqué (*Compt. Rend.*, 1960, **250**, June 20, 4151–4153) This thermogravimetric study of iron alloys of 2–5% nickel shows the influence of the latter on the kinetics of carburation and decarburation of austenite.

Effect of manganese on the austenite–pearlite transformation M. L. Picklesimer, D. L. McElroy, T. M. Kegley jun., E. E. Stansbury, and J. H. Frye jun. (*Trans. Met. Soc. AIME*, 1960, **218**, June, 473–480) Measurements of rate of growth, thermodynamic quantities, and partitioning of Mn are reported for high purity eutectoid Fe–C and Fe–C–Mn steels for the austenite–pearlite reaction. Evaluation of the constants of a derived rate equation with these data indicate that Mn additions cause the decrease observed by increasing the activation energy and apparent activation entropy for the movement of complexes at the interface. Appreciable partitioning of Mn to cementite occurs entirely behind the austenite pearlite interface for more than 30°C of sub-cooling.

Stabilization of austenite by hydrogen E. G. Ramachandran and C. Dasarathy (*Nature*, 1960, **187**, Aug. 20, 684–685) A letter. A method of austenitizing retaining H_2 in the metal has not been found, but increasing the H_2 content of metal still austenitic and before transformation to martensite has been effected.

Mechanism of martensite transformation in ferro-alloys M. Doi (*Bol. ABM*, 1960, **16**, July, 497–518) A new mechanism of the 'double shear' type is proposed. The homogeneous shear arises from the movement of a transformation dislocation, the orientation relationships can be established principally by two types of movement of this dislocation. On the other hand, the habit plane can depend on the kinetics of the stress relief undergone by the transformation dislocation; from the kinetics proposed the operative glide plane observed in martensite in an Fe–30%Ni alloy can be deduced (20 refs).—P.S.

Evidence of a micro relief, indicative of martensitic shear H. Bibring (*Acta Met.*, 1959, **7**, Oct., 684–685) [In French] A letter. Thin layers of a Co–Ni alloy have been examined under the electron microscope. Electron bombardment brought the surface above 265°C, the $\beta \rightarrow \alpha$ transformation temp., and produced a micro relief supporting a mechanism of martensitic shearing.—A.G.

Retained austenite and the tempering of martensite S. Matas and R. F. Hehemann (*Nature*, 1960, **187**, Aug. 20, 685–686) A letter. A discussion of the effects of austenite in the first stage tempering reaction and in bainite formation is given and studies of C partition are briefly described.

Martensitic transformation of low carbon 18–10 austenitic steels during deformation at low temperatures J. Ménard and L. Weil (*Compt. Rend.*, 1960, **250**, June 20, 4160–4162) It is shown that traction tests repeated more than 10^3 times change neither the quantity nor the texture of the martensite formed by deformation between 20° and 270°K. The quantity formed, a function of the temp., declines, at equal pressure to below 140°K.

Morphological characteristics of martensitic structures E. E. Lahteenkorva and R. F. Bunshah (*WADC TR* 54–330; *PB* 130380, 1954, Sept., pp.42; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 121; no abstract).

Rates of martensite reactions in metals E. E. Lahteenkorva and R. F. Bunshah (*WADC TR* 54–331; *PB* 130381, 1954, Sept., pp.39; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 123; no abstract).

The mechanism of the swelling of iron and graphitized steel A. A. Baranov and K. P. Bunin (*Lit. Proizv.*, 1960, (1), 33–35) Experimental results justify the conclusion that during the swelling because of oxidation and the $\alpha \rightleftharpoons \gamma$ transformation, the increase in volume is due not only to the formation of cracks and of oxides of small density but also to the formation of small diffusion micropores due to the partial diffusion coefficients of iron, oxygen, and silicon being so very different.

Studies on low-Mn high-strength steel. II. Effect of various alloying elements on low-temperature transition properties of 2%Mn high-strength steel T. Saito and T. Fujiwara (*Tetsu to Hagane*, 1960, **46**, Jan., 34–38) The transition temp. was much reduced with C < 0·15%, but in the range 0·20–0·35% the reduction in C did not always improve transition properties. Additions of Si, Cr, W, Ti, Ti–B, and Cu were deleterious to the transition properties. Mo (0·5–0·6%) and V (*c.*0·1%) were effective addition elements (16 refs).

Study of transformations $\gamma \rightarrow \beta$ and $\beta \rightarrow \alpha$ of the binary alloys uranium–chromium, uranium iron, and uranium–molybdenum of low chrome iron or molybdenum contents during rapid cooling J. Delaplace and R. Bigot (*Compt. Rend.*, 1960, **250**, June 20, 4157–4159) The rapidity of cooling has little influence on the temp. at the beginning of the $\gamma \rightarrow \beta$ transformation of the alloys U–Cr and U–Fe and the $\beta \rightarrow \alpha$ transformation of the alloys U–Fe. It has however an important effect on the $\gamma \rightarrow \beta$ transformation of the alloy U–Mo at 2·8 at Mo% and particularly on the $\beta \rightarrow \alpha$ transformation of the alloys U–Cr. These observations are valid for cooling speeds below 5000°C/mm.

Change-over from elastic to permanent deformation during structural transformations D. M. Nakhimov (*Metallov. Term. Obra. Met.*, 1959, (3), 2–6) A description is given of work in which specimens were tempered while under stress (in the elastic range). The effect of preliminary tempering is considered. The effect of the martensite transformation on elastic deformation of steels in various states of temper was also investigated, and the use of clamping of parts in jigs during hardening in order to avoid distortion, was mentioned.

A modified phase diagram for stainless steel weld metals W. T. DeLong (*Met. Prog.*, 1960, **77**, Feb., 98–100) The revised diagram proposed accounts for the austenitizing effect of nitrogen in the welding rod.

Solubility of vanadium carbide in γ-iron N. A. Savost'yanova and L. A. Shvartsman (*Fiz. Met. Metalloved.*, 1960, (4), 515–519) It has been shown that the effect of Mn on the transition of the sparingly soluble V_4C_3 into austenite may be interpreted as due to the fact that the presence of Mn in the solid solution reduces the activity coefficient of carbon.

The effect of nickel on the rate of nucleation and growth of hypoeutectoid ferrite K. Mazanec, J. Čádek, and J. Likeš (*Hutn. Listy*, 1960, **15**, (4), 282–287) The effect was studied in two steels containing 0·30% C, 0·30% Mn, 0·25% Si, and 1% Cr, the Ni content being either 0·04 or 1·17%. It was found the Ni depresses appreciably the rate of ferrite growth, particularly with high degrees of supercooling, i.e. at 700–650°C. The effect on the rate of nucleation could not be ascertained. The rate of growth is determined mainly by the rate of diffusion of carbon in austenite, the activation energies being close to 30 kcal/gram atom in both steels. An analysis of the isothermal ferrite reaction yielded an activation energy of about 36 kcal/gram atom, and led to the conclusions that not only the growth rate but the entire kinetics of ferrite formation was controlled by the diffusion rate of the carbon.—P.P.

Transformation and properties of the iron–nitrogen phases after isothermal holding I. E. Kontorovich and L. G. Emel'yanova (*Fiz. Met. Metalloved.*, 1960, (2), 216–223) The surface layer obtained in nitriding at 670° consists of a mixture of $\alpha+\gamma'$ phases which change little with a reduction in the temp of holding. Both the microscopic picture and the hardness persist in all the temp and periods of ageing investigated. Even a sharp quenching in water does not change appreciably the microstructure and hardness of the layer. This layer forms during ageing in the nitriding operation. The kinetics of formation of the surface layer are in good agreement with the corresponding phase diagram of the Fe–N system. At 550° the decomposition of a eutectoid type takes place showing decreased hardness. At 500° the rate of austenite decay and the resulting lower strength characteristics do not depend on the N content in the nitrided layer.

The condition of the crystalline lattice and the density of dislocations in the phase transformations of steels L. I. Mirkin and Ya. S. Umanskii (*Fiz. Met. Metalloved.*, 1960, (6), 897–902) The fine intergrain structure of type 45 steel (0·4%C) and of a steel with 0·4%C and 12%Mn) after quenching from 920–1200° and annealing at 200–700° was studied. The question of selecting a standard to determine the dimensions of the blocks with distortions of the IInd order is discussed. The method of determining the density of dislocations by the widening of the lines on X-radiographs is proposed for investigating the processes of thermal treatment.

Graphitization of SG-iron on tempering P. Ryš (*Slévárenství*, 1960, **8**, (4), 141–148) A detailed study was made of the kinetics of graphitization and of the variables affecting the process.—P.F.

Investigating the decomposition of the supersaturated solid solution in manganese steel M. I. Zakharova and Van Chua-Fu (*Fiz. Met. Metalloved.*, 1960, (2), 235–242) It has been shown that the disorientation of the blocks of the original solid solution does not increase continuously with an increase in the size of crystals, but that after attaining a maximum it diminishes again. A reduction in hardness and impact strength with the coagulation of the phase being eliminated was observed in many investigations and the diminution of these indices is due only to the increase in the size of the foci beyond a critical limit because of the increase in the surface area of the precipitated phase.

Investigating the martensite transformation in the isolated austenite of the carbon-free iron alloys A. P. Gulyaev and V. D. Zelenova (*Fiz. Met. Metalloved.*, 1960, (4), 525–529) By electrolytically dissolving the Kh17N9 austentic alloy, powders are obtained each particle containing the $\alpha+\gamma$ phases. After subsequent heating to 1100° the powders consist only of the γ-phase. The monocrystalline particles of γ-phase do not undergo a martensite transformation on cooling, whilst the complex polycrystalline specimens of the same composition do undergo this transformation. The particles obtained electrolytically of the mixture of the $\gamma+\alpha$ phases undergo this martensite transformation on cooling.

Concerning the non-diffusion transformation of martensite into austenite V. N. L'nyanoi and I. V. Salli (*Fiz. Met. Metalloved.*, 1960, (3), 460–463) The paper is a criticism of the one by Sokolov and Sadovskii (*ibid.*, 1958, **6**, (3)) The conclusions there reported regarding the non-diffusion transformation of martensite into austenite are refuted on the strength of new experiments here reported, which show that with any rate of heating between 200°/min to 800°/sec, martensite contours persist and only disappear when the specimens are kept at high temp for sufficient time to allow the cementite to dissolve.

Regarding the possibility of non-diffusion formation of austenite when heating steel V. D. Sadovskii and B. K. Sokolov (*Fiz. Met. Metalloved.*, 1960, (3), 463–465) A reply to the criticism of L'nyanoi and Salli (previous abstract). The possibility of the existence of a special non-diffusion mechanism for the formation of diffusion mechanism for the formation of austenite is maintained. When heating quenched steel the original austenite grains are regenerated.

The autocatalytic effect of the martensite transformation O. P. Maximova and E. I. Estrin (*Fiz. Met. Metalloved.*, 1960, (3), 426–436) The appearance of an autocatalytic effect during the martensite transformation has been confirmed by the analysis and mathematical treatment of the data obtained from many experiments carried out to investigate the kinetics of the martensite transformation in Fe–Ni alloys. It has been shown that the early appearance of isolated martensite crystals exerts an autocatalytic effect on the later transformation.

CORROSION

The fight against corrosion P. Chaumond (*Mét. Electr.*, 1960, **44**, May, 55–56) The work on cathodic protection undertaken by the specialized Belgian organization CEBELOR (Centre Belge d'étude de la corrosion) and its scope are briefly indicated.—S.H.-S.

UNI tables on the corrosion of metallic materials (*Acciaio Inossid.*, 1960, **26**, (6), 271–272) This is a brief explanatory note regarding the methods of carrying out laboratory tests for continuous immersion in aerated solutions set out in UNI 4261 and 4262.

Investigating corrosion resistance of s.g. cast irons alloyed with silicon T. Dumitrescu (*Met. si Constr. Masini*, 1960, (1), 24–31) It has been experimentally established that s.g. irons alloyed with Si are also superior to lamellar graphite irons as regards dimensional stability at high temp and resistance to oxidation. These irons may be divided into two groups according as their Si content is below or above 4·5% Si. The irons of the first group are resistant to oxidation up to 850°, dimensionally stable at high temp, have good tensile and bending strength and are easily workable. The second group irons resist oxidation up to 950° have increased dimensional stability and tensile strength but are slightly less ductile and more difficult to machine than those of the first group.

The conditions for the formation of iron oxide incrustations N. N. Man'kina (*Teploenergetika*, 1960, (3), 8–12) The greatest amount of damage to pipes is caused by boiling incrustations on their internal surfaces, the so-called iron oxide incrustations. The article reports on investigations concerning all the factors concerned in their deposition, concentration of iron, pH, heat load, valency of the iron, conditions of boiling, temp variations and the presence of different substances. The findings show that treating the water with hydrazine is an effective means of preventing such deposits.

Investigating corrosion resistance of s.g. cast irons alloyed with silicon T. Dumitrescu (*Met. si Constr. Masini*, 1960, (2), 101–106) The resistance to corrosion of these irons in an acid medium is here considered and experiments are described showing that inoculation of a s.g. cast iron with Mg results in a material with low carbon content within the limits prescribed for acid-resistant irons. Mg treatment reduces gas content and improves mechanical properties.

Study of the scale formed on sheet during hot rolling M. Cagnet and J. Moreau (*Rev. Mét.*, 1960, **57**, May, 437–444) Scale from three types of hot-rolled dead-mild steel (Thomas, oxygen-blown Thomas and OH steel sheet) was examined microscopically, and thickness, compactness, adhesiveness and composition of the scale determined. Operational factors influencing the type of scale are also studied statistically.

Removal of scale from steel rod by stretching K. Sachs and T. Pitt (*JISI*, 1961, **197**, Jan., 1–8) [This issue].

Studies on cathodic protection using the Hull cell. I. Action of corrosion inhibitors K. S. Rajagopalan and Y. V. P. Ramachandra Row (*J. Electrochem. Soc.*, 1960, **107**, May, 379–385) In the study of inhibitor action it was found that the action of acid inhibitors is changed substantially under an impressed current. The potential of the cathodically protected metal is not a fixed value but changes in the presence of an inhibitor. The inhibitor efficiency of four inhibitors examined was: thiourea > gelatine > β-naphthol, > quinoline.—T.G.

Corrosion and activity build-up in a power reactor C. R. Bergen and J. Chupak (*Ind. Eng. Chem.*, 1960, **52**, Aug., 699–702) Films of corrosion products deposit and disperse from the stainless steel surfaces but the thickness increases at a decreasing rate while the activity builds up at an increasing rate. Inhibiting redeposition may be the best solution.

Intercrystalline failure of stainless steel in saline water T. K. Ross (*Corros. Techn.*, 1960, **7**, April, 122) Tubular gas coolers made of 18/8 Ti-stabilized steel which behaved normally in the Huey 65%HNO_3 test, the $MgCl_2$ test, and the Hatfield acidic copper sulphate test failed due to intercrystalline cracking. Numerous pits and channels were formed, many of which completely penetrated the tube wall with the formation of a corrosion product containing Cr and Ni. The coolant in the tubes was neutral well water containing 2000 ppm chlorides, and about 40 ppm total O_2 content. It was shown that the chloride was responsible for initiating the cracking, but that this was greatly sensitized by the presence of O_2; also the extension of cracking was entirely intercrystalline in the presence of both Cl^- and O_2. Hence it is concluded that relatively low saline concentrations in association with oxidizing conditions can cause this type of corrosion.

The rusting of copper–aluminium alloys containing iron P. J. le Thomas, D. Arnaud, and A. Lethuillier (*Rev. Mét. Mém. Sci.*, 1960, **57**, April, 313–323) A study of the Fe-containing constituent shows that the solid solution of this constituent is responsible for the rusting process. The effect of Ni additions is considered (10 refs).

An investigation of intergranular oxidation in stainless steel M. J. Sinnot and C. A. Siebert (*AD*–46901; *PB* 130018, 1954, Oct., pp.39; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 121; no abstract).

Growth of sulphide films on steel R. B. Campbell, L. Grunberg, and H. M. Scott (*Nature*, 1960, **187**, Aug. 13, 588–589) A letter. Extreme pressure lubricant action was examined, the films being produced by dibenzyl sulphide or by free S labelled with ^{35}S.

Effects of cycle frequency on corrosion fatigue strength [of carbon steels] K. Endo and Y. Miyao (*Bull. JSME*, 1958, **1**, Nov., 374–380) Fatigue tests of three materials under alternating plane and rotating handling were made at various cycle frequencies with corrosion in tap water and in salts. At low frequencies the number of breaks is less than at high frequencies. Stress σ_e given under corrosion fatigue increased to $\sigma_e k$ owing to notch effects of corrosion pits. For corrosion fatigue fracture under varying stress amplitudes the cumulative damage criterion $\Sigma n_1/N_1=1$ was found to be applicable.—S.H.-S.

Stress-corrosion cracking of steel in molten zinc W. O. Wetmore and G. C. Woolsey jun. (*NOTS TM*–170; *PB* 129644, 1948, Nov., pp.159; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 124; no abstract).

The A–C resistance of a stainless steel electrode and specific adsorption G. M. Schmid and N. Hackerman (*J. Electrochem. Soc.*, 1960, **107**, July, 647–651) The ac resistance of a stainless steel wire electrode was measured as related to the type of electrolyte, the polarizing current density, and the frequency of the measuring current. K^+ was shown to be more adsorbed than Na^+ during cathodic polarization, and Cl^- more than F^- during anodic polarization. The method seems suitable for testing the adsorbability of neutral surface active substances during dc flow.—S.H.-S.

The effect of additives on the water-induced pitting of ball bearings L. Grunberg and D. Scott (*J. Inst. Petroleum*, 1960, **46**, Aug., 259–266) Commercial *iso*amyl alcohol was most effective. Oleic acid and triethanolamine increased pitting. Phenoxyacetic acid and proprietary 'dewatering' agents were not effective, nor were benzoate and nitrite. The results are discussed.

Basic requirements of corrosion control. (*Corros. Techn.*, 1960, **7**, Apr., 114–117). Marine cathodic protection is discussed, and methods capable of providing complete and continuous

protection of all unwerwater portions of a ship's hull are reviewed.

Anticorrosive materials and products P. Badot (*Galvano*, 1960, **29**, Feb., 89–92) This note summarizes the anticorrosive properties of various materials including pure iron, non-alloy mild steel, stainless steels, an austenitic steel, silicon, pig iron, and various non-ferrous alloys and non-metallics.

Pipes and fittings to best corrosion (*Corros. Techn.*, 1960, **7**, July, 220–223) Some data are given of pipes and fittings in metals and plastics, shown at the first Pipes and Pipelines Exhibition held at Earl's Court.

Field evaluation of cathodic protection of casing [for oil wells] W. D. Greathouse, J. J. Lehman, J. E. Landers, and J. D. Sudbury (*J. Petr. Techn.*, 1959, Dec., 354–360) External corrosion of new pipes in dry wells was noted over a two-year period, with currents of respectively 12, 4, and 0 amps. The 12-amp current showed no significant damage and the 4-amp tube only over a 6-ft zone. Corrosion damage and profile potentials are correlated.

Protection of metals. I. Cathodic protection in the fight against metallic corrosion M. Serra (*Rev. Ciencia Apl.*, 1960, **14**, May–June, 206–216) In a review of the numerous investigations of the problem, the author stresses its importance and discusses the principles of cathodic protection as a method of reducing or preventing corrosion. Methods of using either impressed currents or local electrolytic cells are considered. It is concluded that cathodic protection reduces the corrosion rate by over 75% and its cost is less than that of protection by protective coatings alone (66 refs).—P. S.

Cathodic protection of boiler systems K. Sautner (*Mitt. Forschungs. Blechverarb.*, 1960, (15–16), Aug. 10, 198–203) A lecture delivered at a meeting of the society, reviewing the present-day trend in cathodic protection and pointing out that the actual savings are very much greater than the expenditure for the cathodic protection.—T. G.

Design for pipelines—part 1 D. Spector (*Corros. Techn.*, 1960, **7**, April, 103–106) Details are given of the cathodic protection system of the 6-in product pipeline from Haifa to Tel Aviv and the 16-in crude oil Ashdod-Haifa pipeline. **Part 2** (July, 213–216). In this section specific design problems and illustrations of the work, commission, and reporting, in connexion with the cathodic protection of these pipelines.

Cathodic protection—review of marine applications R. H. Hopwood (*Corros. Techn.*, 1960, **7**, April, 118–120) The use of cathodic protection systems for the corrosion protection of ballast tanks and other marine applications is described.

Cathodic protection systems for steel in sea-water, calculation of mat sizes and spread of protection W. C. G. Wheeler (*Corros. Techn.*, 1960, **7**, July, 209–212) Comparatively simple formulas are given for calculating spread of protection over large continuous areas, according to the distance of the anode from the cathode.

Cathodic protection of ships' hulls Standard Telephones and Cables Ltd (*Brit. Eng. Transport*, 1960, **43**, Sept., 48–49) An account of the Sen Ter Cet equipmment.

Corrosion resistance of stainless steels. VI. Corrosion under stress G. Colombo (*Acciaio Inossid.*, 1958, **25**, (6), 173–185) The nature of the stress is described and also the nature of breaking under stress, examples of corrosion under stress and methods of lessening the danger of corrosion under stress occurring are given. **VII. Pitting, I** (1959, **26**, (1), 5–12) This first article examines more closely the phenomenon of pitting and considers generally the problem of electrochemical attack. It is shown that at present there is no theory which can satisfactorily explain the mechanism of pitting. **VIII. Pitting, II** ((2), 37–53) The second article in the series discusses the quantitative influence of the various factors connected with pitting are examined. A critical analysis is given of the methods of studying pitting made recently by V. B. Greene and M. J. Fontana. The various theories and ideas to explain the phenomenon of pitting are described. From a study of the pitting of steel by electrochemical attack using an artificial crater, instantaneous polarization diagrams were drawn up. The authors affirm that pitting is in essence autocatalytic and affects not only the anode crater but also the cathode. **IX. Pitting, III** ((3), 85–101) This final article on pitting examines the various factors involved in pitting and advises on steps which must be taken to combat it effectively. The influence of constituents, heat treatment, surface finishing, corrosive atmosphere, and the usefulness of protective agents are described for the main types of steel. **X** L. Morsing ((4), 125–139) This article describes the physical and mechanical properties of the sigma phase and its effect on corrosion resistance and mechanical properties. Table V summarizes the behaviour of stainless heat-resistant steels in the sigma phase. **XI** ((5), 177–221) The article describes the general characteristics of the sigma phase and the conditions under which it develops for pure Fe and Cr, Fe, Cr, and Ni alloys, and commercial alloys. Its influence on mechanical characteristics, corrosion resistance, and welding is dealt with. Means of identifying the sigma phase by X-rays and metallographic means are detailed. It is concluded that as far as corrosion of stainless steels is concerned it is difficult to distinguish between the effects of the sigma phase and of carbide precipitation. **XII** ((6), 245–260) This article describes the effect of the sigma phase and carbide precipitation on intergranular corrosion of 316 and 316L stainless steels and describes tests which aim at distinguishing between the two effects (80 refs). **XIII. Effect of the sigma phase and carbide precipitation on intergranular corrosion resistance of stainless steels 316 and 316L** (1960, **27**, (1) 317–345) The conclusion resulting from this investigation is that the presence of a continuous network of precipitated carbides at the grain boundaries makes 316 steel susceptible to severe attack in presence of sulphuric, lactic, acetic, oxalic, citric, and phosphoric acids. For 316L steel the sigma phase does not produce severe intergranular attack by any of the corrosive agents considered. If the sigma phase is present in continuous form at the grain boundaries, 316L is severely attacked in the standard test by nitric acid. The study recommends the adoption of a standard method of testing 316L steel which must be sensitive to Cr carbides precipitated without being affected by sigma. A 10%HNO_3+3%HF is suggested. **XIV. Knife line attack in stabilized stainless steels** G. Colombo ((2), 397–412) The conclusions are that knife line attack occurs in welded stabilized steel type 347 and 321 welded and thus exposed to stress relieving or in some way exposed to temp. between the range of sensitization in the presence of HNO_3 or its mixtures. It is necessary to show that only stabilized steels do not require stress relieving. The latter may only be necessary when owing to the presence of chloride or similar solutions a corrosive attack is likely during operation. In these cases as in those in which there will be operation at temp. between the interval of sensitization and the presence of very corrosive fluids, steel restabilization treatment must be carried out after welding to reprecipitate the carbides of the stabilizing element at temp. of the order of 850–900°C (stress relieving-treatment) or even at 1050°C (normal annealing treatment).

A speeded up method of assessing the tendency of metals to corrosion cracking V. N. Gulyaev, P. A. Akol'sin, E. N. Ivanov, and E. S. Gromova (*Zavods. Lab.*, 1960, (3), 340–341) In the existing method suggested by TsNIITMASh, the chief criterion of the tendency of steels to corrosion cracking is the reduction of their plastic properties in liquid corroding media as compared with air. The article suggests the possibility of adapting this method to austenitic steels in weakly chemically active media. The results with NaOH and NaCl solutions at different temp and with different thermal treatments are tabulated.

Effect of oxygen on the active-passive behaviour of stainless steel N. D. Greene, (*J. Electrochem. Soc.*, 1960, **107**, May, 457–459) The presence of O_2 has no apparent effect on the anodic dissolution kinetics of type 430 stainless steel. The primary passive potential and the critical anodic current density are essentially the same in the presence or absence of dissolved O_2. These results are, however, not consistent with adsorbed O_2 theories of passivity. (14 refs.)—T. G.

Corrosion studies on the steel tubes of an experimental evaporator in the sugar industry H. Giesecke, W. Hofmann, A. Emmerich, and F. Schneider (*Werks. Korros.*, 1960, **11**, June, 337–347) Corrosion in the evaporator tubes, formerly considered to be due to O_2, was found to be partly caused by the entry of Cu, leading to the formation of electrolytic cells. (22 refs.)

Kinetic relationships between accelerated and natural corrosion K. Bartoň and E. Beranek (*Werks. Korros.*, 1960, **11**, June, 348–351) A description is given of an accelerated test the results of which are comparable with those of natural corrosion tests. The tests were carried out on carbon steel and zinc. A method of calculating the acceleration coefficient is given.

The corrosion resistance of 13KhM steel in distilled water at 330° under a pressure of 130 kg/cm². V. V. Gerasimov and A. L. Gromova (*Teploenergetika*, 1960, (4), 42–47) The investigations were carried out in distilled water saturated with air or oxygen and with additions of hydrazine. The findings shows that at high pressures and temp the corrosion of this steel is of an electro-chemical nature. The rate of the cathode process is conditioned by oxygen diffusion into the metal surface.

Electrical resistance method for investigating corrosion and failure of steel at high temperatures E. A. Kovalev (*Zavods. Lab.*, 1960, (3), 296–298) To determine the moment of the appearance of cracks which later cause failure of the metal under stress, a relation between the destruction of the 'compactness' of the metal (appearance of cracks) and the changes in the electrical resistance caused by these cracks was investigated. A special apparatus is described. Equations have been evolved to calculate the critical reduction in the dia. of the specimen and the rate of corrosion from the electrical data. This method may be used to investigate the kinetics of scale formation and of metal failure at high temp.

Charging curves to investigate the passivation of steels and their tendency to point corrosion V. P. Maksimchuk and I. L. Rosenfel'd (*Zavods. Lab.*, 1960, (3), 288–290) A method is described for determining the resistance of passivated steel to point corrosion by means of the charging curves plotted with a special apparatus with automatic potential recording. 1Kh18N9T and Kh18N12M3T steels were investigated in 0·1 *N* NaCl. Anode charge curves were plotted first with a very slow rate of feeding the strip through the machine, which shows the range of fluctuations, and then with a very rapid rate of feed, from which the form of the fluctuations may be seen. Tables are given for the rate of fluctuations per min and for the limiting values of these fluctuations, from which the changes in the potentials may be obtained.

Electronic constant voltage source and its use for elucidating structural corrosion of stainless steels M. N. Fokin, N. M. Kurtepov, V. K. Zhuravlev, and A. F. Vinogradov (*Zavods. Lab.*, 1960, (2), 219–223) Schematic diagrams are given for a few types of electronic constant-voltage sources by means of which it is possible to study structural corrosion of stainless steels over a wide range of potentials, excluding the unstable transition range from the active to the passive state of the metal.

Protecting the pipes of the heating network from external corrosion by non-metallic materials V. B. Vital'ev and D. A. Grosman (*Teploenergetika*, 1960, (4), 47–52) The use of new non-metallic materials has given good results. These are derivatives of bitumen and are recommended by the VNII Asbestos Cement. For example Borulin, which consists of 70–75% bitumen and 25–30% asbestos; Izol, consisting of rubber crumbs: Borulin putty; silicon-organic compound mixtures, etc. These have increased the service life of pipes and their use has allowed a reduction in the thickness of the pipe walls and thus has saved great amounts of steel.

ANALYSIS

Regarding rapid steel analysis at high temperatures L. V. Meandrov, I. Ya. Tarnovskii, and A. A. Pozdeev (*Zavods. Lab.*, 1960, (2), 201–203) To obtain reliable data regarding the resistance of alloy steels to deformation at high temp, 16 types of steel were investigated at 900–1200° during rapid upsetting, on a friction press operating at a speed of 180 mm/sec corresponding to a deformation rate of 7·5 s^{-1}. The special apparatus and the oscillograph curves are explained.

Differential determination of oxygen in metals by bromination-reduction R. Durand and F. Nouyrigat (*Rev. Mét.*, 1960, **57**, April, 347–353) Dissolved or oxide O is transformed into CO by bromination in the presence of C at 1000°C; the CO is oxidized to CO_2 and determined conductimetrically. Dissolved and combined O can in some cases be differentiated (12 refs.)

The determination of oxygen, hydrogen and nitrogen in steel by vacuum melting M. Kaše and M. Mandl (*Hutn. Listy*, 1960, **25**, (3), 195–200) The development and use of equipment for the gas analysis of steels are described.—F.F.

A simple method of boron determination in steels E. Mustacescu (*Met. si Constr. Masini*, 1960, (3), 244–246) The method is an adaptation of the Russian method evolved for determination in ores containing 0·01–0·5% B; (Knipovich and Moracheskovo '*Analiz mineral'novo syriya*' Leningrad, 1956), to steels, and is based on the property of mannitol-boric acid of liberating iodine from an iodate-iodide solution. It is claimed that this method does not require special apparatus such as quartz containers, nor twice-distilled water, etc. Ordinary reagents are used and the analysis is relatively rapid, taking about 5 h. The accuracy is ±0·000 3%. The method can be used in factory laboratories.

Application of chromatography in the gaseous phase to determine hydrogen, nitrogen and oxygen in steels and castings P. Tyou (*Hierro y Acero*, 1960, **13**, April, 383–391) After describing the principles of gaseous chromatographic separation and those of thermal and ionization conductibility by beta-rays, the practical uses of H_2 and A as eluent gases in chromatography for the purpose of securing appreciable sensibility optima in quantitative analysis are described and compared.—S.H.-S.

Investigating the accuracy of spectrographic OH slag analysis K. I. Ionova (*Zavods. Lab.*, 1960, (5), 581–587) An important portion of the total error involved in the spectrographic analysis of OH slags in solution is the error due to the uncontrollable conditions of the passage of the slag into solution. A change in the acidity of the solution reduces accuracy. The acidity must be kept as constant as possible. An increase in the weighed amount by a factor of 2·5 does not change the total error.

A plasma source for the spectral analysis of slags Yu. K. Kvaratskeli (*Zavods. Lab.*, 1960, (5), 557–559) An arrangement for a new type of light source termed a 'plasmatron' is described. Inside a chamber under a pressure of 0·4–0·7 atm. is introduced a monoatomic gas (argon). An anode and a disc-shaped cathode are placed in the chamber. The plasma of a dc arc emerges from the chamber through openings in the cathode after absorbing the gas. A large proportion of the plasma escapes and the discharge assumes the shape of a tongue. The portion of the tongue outside the chamber is the source of light. Its temperature reaches about 10 000–11 000°K.

Reports of 19th Committee, 1st Sub-Committee (Analysis) Japanese Society for the Promotion of Science (*Tetsu to Hagane*, 1960, **46**, July, 803–807).

The determination of hydrogen in steels (with particular reference to welding J. T. Berry and R. C. Allan (*NCRE/R*, 379, 1957, Oct., pp.49) A critical review of previous work and a description of apparatus for welding in controlled atmospheres and for the determination of H_2 are given. 'Diffusible' and 'residual' H_2 are discussed (104 refs).

Determination of hydrogen in metals: a carrier gas method F. R. Coe (*Research*, 1960, **13**, Aug., 323–327).

Mass spectrometric examination of gases in chromium-plated steel. I. Hydrogen C. Levy and G. A. Consolazio (*WAL* 691 1/43; *PB* 127573, 1955, March, pp.21; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 30; no abstract).

Determination of nitrogen in steels J. Llop Llop (*Inst. Hierro Acero*, 1960, **67**, May, 532–535, *Special Number*) It is pointed out that the standard methods for N_2 determination take from 2 to 8 h. A method which employs a new distillation apparatus is described; with this the determination time is some 20 min and the method is very suitable for bath control purposes.—P.S.

The vacuum fusion method of analysis for determination of minute quantities of gases in metals W. McMahon and L. S. Foster (*WAL* 805/5–1; *PB* 127555, 1952, Nov., pp.13; from *US Govt. Res. Rep.*, 1960, **33**, Supplement, April, 30; no abstract).

Rapid methods of potentiometric estimation of tervalent chromium J. Allard, M. Bonnemay, and C. Darrécamp (*Chrome Dur.*, 1959–60, 33–39) This article describes in detail the techniques employed in measuring potentiometrically tervalent chrome.

Separation of niobium and tantalum by liquid extraction D. I. Ryabchikov and M. P. Volynets (*Zhur. Anal. Khim.*, 1959, **14**, (6), 700–704) The effect of various conditions on the distribution of Nb and Ta fluoride complexes between aqueous and tributyl phosphate phases is examined, and a method of separation suitable for the analysis of binary Ta–Nb alloys developed (25 refs).

Analytical applications of 8-mercaptoquinoline (thioxine) and its derivatives, 8-New photometric method for the determination of rhenium in the presence of molybdenum, tungsten and other elements Yu. A. Bankovskii, A. F. Ievin'sh, and E. A. Luksha (*Zhur. Anal. Khim.*, 1959, **14**, (6), 714–720) Re thioxinate is formed in 5–11·75 N HCl, and determined photometrically in concentrations of 5–200 γ or more, in the presence of relatively large excesses of the above and other elements (36 refs).

Analytical chemistry of zirconium. I. o-Cresotic and 4-aminosalicylic acids in the determination of zirconium V. V. Subbanna and A. K. Bhattacharya (*Anal. Chim. Acta*, 1960, **23**, Aug., 145–146) Th is not separated and Fe, Cu, or uranyl require double pptn.

Polargraphic analysis of impurities contained in iron ores G. Odone and G. Picasso (*Chim. e Ind.*, 1960, **42**, (6), 598–605) A series of rapid methods for the polarographic determination of the contents of the following elements in iron ores have been developed. Cu, Pb, Zn, Ni, and Sn. Special precautions eliminated interference by certain ions. These rapid methods give much more accurate values than those resulting from ordinary chemical methods. Analysis by this method can be completed within 2 h, a considerable reduction compared with previous practice.

Determination of sulphate in chromium plating solutions G. L. McKinley and A. Quinlan Jones (*Plating*, 1960, **47**, June, 634–636) An evolution method for the determination of sulphate is described. Sulphate is reduced to sulphide with HI–HCl-hypophosphite. Liberated H_2S is trapped in ammoniacal $ZnSO_4$ solution. KI–KIO_3 solution is then used. The method is precise and has an accuracy of ±1%. Time required for a determination is 1½ h.

Spectrophotometric studies and techniques L. Riccoboni (*Met. Ital.*, 1960, **52**, June, 289–305) The theories for the general application of Beer's law are briefly described. The author then examines the correlation between instrumental error and consequent relative error of concentration. The deviation from Beer's law is analysed with indications how with the aid of filter photometers precision can be improved by using integrals of empirical transmittence functions which can be deduced from the absorption spectrum of the substances under examination. After assuming that the light source is monochromatic and allowing a certain instrumental error it is shown that the effect of the error itself on the concentration measurement can be minimized by working within either a determined transmittence or by using a differential technique.

The influence of spectroscopic carbons on spectro-analytical problems H. Rüssmann (*Met. Ital.*, 1960, **52**, June, 280–288) The influence of graphite and carbon on the problems of spectroscopic analysis is examined. The graphite group has a resistivity of 1 750 microhms/cm while the carbon group has a resistivity of 4 500 microhms/cm—for the same excitation energy a difference of 700°K exists between the plasma temp. of the dc arc for the two groups. The regularity of the dc arc flame during the excitation of elements of low ionizing potential (e.g. alkalis) is discussed as well as the thermal conductivity of the electrodes and the effect of the carbon on the analysis of solutions.

A study of the calibration of quantometers R. Passeri (*Met. Ital.*, 1960, **52**, June, 277–279) The type of function is determined which in direct reading spectrometers relates the concentration of an element to the indication on the recording instrument. This is applied to the calibration technique. From the formulae obtained data of practical importance are devised, the value of the zero in a given calibration and the most convenient working straight line for the cases in which the relation between concentration and instrument reading is not linear.

Spectrophotometric methods for the analysis of steels. Part II A. Sommariva and A. Devoti (*Met. Ital.*, 1960, **52**, June, 341–354) This article summarizes the methods in current use at the Ansaldo SPA Genoa, laboratory, for measuring spectrophotometrically the Mn, Ni, Mo, Nb, Ta, W, Ti, V, Co, and Cu content in steels. These methods have been modified in relation to the type of steel examined and the apparatus used. (Spectrophotometer Beckmann. DU with cells from 1 cm thick.)

The determination of phosphorus in steel by direct spectrographic analysis using the quantometer ARL 1·5 m PGQ No.7200 G. Bianchi (*Met. Ital.*, 1960, **52**, June, 331–335) The possibility of determining P in steels containing 0·10 to 0·60%Cu using the P1 2149·11 Å line of the third order is examined. From an examination of the variations on the analytical curve in relation to the experimental conditions the limits of error of the measurements can be deduced. The method used for routine analysis is described.

Spectrophotometric measurement of phosphorus in steel, pig iron, and iron ore using molybdenum blue G. Picasso (*Met. Ital.*, 1960, **52**, June, 358–365) The absorption spectrum of phosphorus blue complex in isobutyl alcohol is different from that obtained in aqueous solutions: two characteristic absorption peaks occur at 625 and 725 mμ respectively. The system follows Beer's law for phosphorus concentration between 5 and 8 γ working with 1 cm cells and at 725 mμ. Various methods are proposed for eliminating interference due to arsenic.

Spectrographic determination of niobium in rocks N. I. Tarasevich and K. A. Semenenko (*Zhur. Anal. Khim.*, 1959, **14**, (6), 705–709) Nb in concentrations of 0·009–0·1% is precipitated on SiO_2 in the presence of gelatine and pyrogallic acid, and determined spectrographically. The method is suitable for determining Nb in gneisses and granites.

A spectrographic method for the analysis of aluminium silicate refractories A. Porta (*Met. Ital.*, 1960, **52**, June, 320–325) The methods described allow for the quantometric determination of SiO_2 and Al_2O_3 in the range of 20 to 75% and the spectrographic determination of low concentration elements (Fe_2O_3–TiO_2–CaO–MgO). The total analysis time, less than 2 h, and the results obtained suggest the adoption of this method for routine analysis.

The present state of spectrometry with fluorescence X-rays A. Giavino (*Met. Ital.*, 1960, **52**, June, 306–314) Only recently has spectral analysis using X-rays been applied on a highly effective industrial scale. This is due mainly to electronic methods of evaluation and also to progress in the production of the primary X-ray beam and to the efficiency of the methods of dispersion. Good results in simple analytical cases can be obtained even with non-dispersive systems which use combinations

of primary excitation frequency with suitable filtering systems. A proportion of the dispersion is obtained by electronic methods.

Elementary analysis by X-spectrography (fluorescence) G. Baron, J. Favre, and C. Raimbault (*Chim. Anal.*, 1960, **42**, Aug., 388–404) The final article in the series.

INDUSTRIAL USES AND APPLICATIONS

High strength heat-treated bolts of type 8t 5 steel L. I. Gladshtein (*Stal'*, 1960, (8), 764–767) A study leading to the replacement of the more expensive type 40Kh is reported.

Stainless steel founding (*Mét. Constr. Méc.*, 1960, **92**, June, 477–481) The use of stainless steel for tanks, pipes, tubes, etc., in the oil industry and also in electric power stations and the precautions to be taken in their use are described.—S.H.-S.

Steel for fastenings in steam-power plant operating at 140 atmospheres (2000 p.s.i.) and 570°C (1060°F) A. V. Ratner and A. S. Panicheva (*Metallov. Term. Obra, Met.*, 1959, (3), 28–32) The development of a pearlitic steel with satisfactory properties for this purpose is described. The composition was 0·24%C, 0·36%Mn, 0·17%Si, 0·032%S, 0·019%P, 1·23%Cr, 0·01%Mo, 0·98%V. It was also found that, after nitriding or boridizing, this steel could be used for spindles for use at this temp.

Development of cold formed light gauge steel structures G. Winter (*AISI Res. Techn. Meet.*, 1959, 53–84) A brief survey of design specifications with illustrations of different forms of light gauge steel construction in the building field and an account of testing methods.

The economy of light-metal construction in building: A comparison with steel and plastics B. König (*Technik*, 1960, **15**, Aug., 529–534) The author shows that the higher price of light-metal constructions as compared with steel is no hindrance to the use of Al alloys, as they have qualities which are in many cases superior to those of steel, for instance lower weight and better corrosion resistance.—T.G.

Stainless steel in building and in architectural decoration A. G. Amoroso (*Acciaio Inossid.*, 1960, **27**, (3), 433–445) The article describes the use of stainless steel in building and architectural decoration with numerous illustrations and summarizes the characteristics of the steels required for these uses and classifies the uses and criteria for the choice of the appropriate quality for use.

Stainless steel in the textile and canning industry (*Acciaio Inossid.*, 1960, **26**, (6), 288–303) These two articles describe and illustrate the use of stainless steel in plant and machinery on show at the International Textile Machinery Exhibition at Milan in 1959 and the 14th International Packing and Canning Fair at Parma in September 1959.

Stainless steels in the chemical industry P. Bachmann (*Corros. Techn.*, 1960, **7**, July, 199–203) The generalized film theory and electron configuration theory are outlined in relation to the corrosion resistance of stainless steel; the uses of these steels in chemical industry, and the corrosion of these steels are discussed.

Stainless steel in the human organism S. Scalia (*Acciaio Inossid.*, 1959, **26**, (4), 157–163) This note gives illustrations of the use of steel in surgery, particularly in false limbs. It is necessary to have a steel which is completely inert chemically with regard to human tissue and for this, type 18/8 stainless has shown itself to be particularly suitable.

Use of stainless steel in the field of nuclear energy (*Acciaio Inossid.*, 1958, **25**, (6), 186–198) This article describes the effect of nuclear radiation on the various elements of which stainless steel may be composed. Tables show the cross-sections for some radioisotopes and their concentration in the various elements. This enables radioactivity to be calculated after exposure to radiation in a reactor and mechanical resistance elongation and variation in hardness following exposure to varying degrees of neutron radiation. Various types of reactor are described in relation to the problems discussed.

Problems concerning steels used in the construction of nuclear reactors L. Scuri (*Calore*, **1960, 31**, May, 253–258) The physical and mechanical requirements of materials used in nuclear reactors are reviewed. It is important that the steel used should not have an excessively high rate of neutron absorption and a list of steels is given which fulfil this requirement. Another important factor is the effect of radiation on mechanical characteristics. Tests show that the adverse effect of radiation became less as temp. increased. It is concluded that account must be taken of the results of various heat treatments in order to select the best method for the various requirements.

HISTORICAL

The 'Eisenbibliothek' in the former monastery 'Paradies' a centre of industrial historical research K. Schib (*Schweiz. Arch.*, 1960, **26**, June, 217–220) [In French and German] A brief survey of the 'Eisenbibliothek' founded in 1948 by Georg Fischer Aktiengesellschaft Schaffhausen. In the first decade the library accumulated almost 20000 books.—T.G.

Abraham Darby (1678–1717) and the beginning of the coke iron industry H. R. Schubert (*Stahl Eisen*, 1960, **80**, 18 Aug., 1160–1162) A short historical account of the first successful application of coke in the production of foundry iron.—T.G.

Case hardening of iron by the Etruscans (*Trattamenti Term.*, 1960, **3**, Jan.–Feb., 5–14, After a brief description of the development of the Etruscan civilization an account is given of investigations made by Prof. C. Pauseri, Director of the Experimental Institute of Light Metals at Milan, into methods of heat treatment used in the manufacture of certain weapons dating back to the 2–4 century B.C.

Ambrose Crowley E. N. Simons (*Brit. Steel*, 1960, **26**, Feb., 48–49, 55) A biographical note of the founder of the Crowley ironworks, Winlaton.

LKAB and its importance for Northern Norway K. Dahlum (*Tek. Ukeblad.*, 1960, **107**, June 23, 525–534) A history of the development of the iron company Luossavaara–Kirunavaara from its formation in 1890 until 1957, when it was largely acquired by the Swedish Government. The importance of Narvik harbour, and the possibilities of increasing exports through various Norwegian harbours are discussed, with particular reference to the new harbour facilities being installed at Rombak Fiord, north of Narvik.

ECONOMICS AND STATISTICS

Iron ore and steel A. W. Knoerr (*Eng. Min. J.*, 1960, **161**, Feb., 118–119, 144) US steel consumption figures and probable trends of iron ore production and requirements over the next few years are estimated.

The struggle to accelerate technical progress in metallurgy must be intensified (*Stal'*, 1960, (8), 10–11) Statistics of production achieved and expected are given in view of the seven-year plan and the 21st Meeting of the Party.

The service life of metal L. L. Zusman (*Stal'*, 1960, (8), 758–762) An economic survey has been made to examine the rate of steel production and machine and other goods replaced which appeared to show that metal was giving a reduced service life from obsolescence and other causes. It is concluded that wear is proceeding at a higher rate with more intensive use and that there will be a tendency for a still further reduction in service life.

Long term trends and problems of the European steel industry (*United Nations Secretariat of the Economic Commission for Europe*, 1959, pp.176) Arising out of the 1949 inquiry by the ECE Steel Committee, in 1956 the Committee decided on a further comprehensive inquiry into long-term requirements of steel products in Europe and the rest of the world for the next 15 years. The outcome of this inquiry is a series of interrelated forecasts in which the many aspects of steel production are reviewed and future trends are indicated in a report by the ECE secretariat, without in any way attempting to lay down a 'plan' or 'programme' for the steel industries of the world.—S.H.-S.

Operative planning in the iron and steel industry (part I) L. Mayre (*Neue Hütte*, 1960, **5**, June, 313–322) Planned operations and dispatch systems with reference to East German practice are described. **II** (July, 399–406) The central planning of the output of the various iron and steelworks of the German Democratic Republic as customary in socialist countries is described and the difficulties arising from such central planning are indicated.—T.G.

Production planning for an integrated steel plant A. E. Lawrence (*Iron Steel Eng.*, 1960, **37**, May, 133–139) A general review is given of the background, organization, and functioning of production planning at division and works level in integrated steelplants.

Stainless steel at the 38th Milan Fair (*Acciaio Inossid*, 1960, **27**, (3), 446) This is a brief note on the growth of the demand for stainless steel as evidenced by the exhibits and stands at the Milan Fair. No strikingly new uses are noted.

Chrome J. W. Warde (*Eng. Min. J.*, 1960, **161**, Feb., 142–144) Consumption and production of chrome ore in the US for 1959 are discussed, and comparative histograms for earlier years are reproduced.

Cobalt J. H. Bilbrey jun. (*Eng. Min. J.*, 1960, **161**, Feb., 137–138) 1959 production and consumption figures for the first nine months are given and analysed.

Columbium–tantalum W. R. Barton (*Eng. Min. J.*, 1960, **161**, Feb., 126) Production of Nb–Ta concentrate, the metals and their alloys, and their outlook are discussed.

Manganese J. M. Warde (*Eng. Min. J.*, 1960, **161**, Feb., 140–141) Estimated production, consumption, imports, and stocks in USA for 1959 are compared with similar data for earlier years.

Molybdenum W. McInnis (*Eng. Min. J.*, 1960, **161**, Feb., 138–139) Production, consumption, and prices of Mo and Mo products for 1959 are reviewed.

Nickel J. H. Bilbrey jun. (*Eng. Min. J.*, 1960, **161**, Feb., 139–140) 1959 production and consumption statistics are given.

Titanium D. P. Eigo (*Eng. Min. J.*, 1960, **161**, Feb., 133–134) Production, market position, and prospects of sponge Ti and Ti alloys are discussed.

Tungsten R. W. Holliday (*Eng. Min. J.*, 1960, **161**, Feb., 139) US production and imports of W for 1959, prices, and research programmes are outlined.

Vanadium D. P. Eigo (*Eng. Min. J.*, 1960, **151**, Feb., 144) Estimated 1959 consumption of and production of high-purity V, Ferro-V, V oxide, etc., are summarized and compared with the 1958 figures.

MISCELLANEOUS

Technical information services in Germany, Luxembourg, Belgium and Holland R. Sewell (*Aslib Proc.*, 1959, **11**, Oct., 240–265).

Symposium on pilot plants in metallurgical research and development (*Iron Steel Rev.*, 1959, **3**, Aug., 39–40) The objects and scope of the symposium are reviewed.

Conference on the comprehensive mechanization and automation of metallurgical plants M. P. Zolotarev (*Stal'*, 1960, (7), 671–672) Brief abstracts of some of the 40 papers delivered at Kuznetsk in March are given.

Steel plant uses of data processing in providing, scheduling and shipping W. N. Spray (*AISI Reg. Techn. Meetings*, 1959, 147–160) A brief survey of machine data processing and of the plethora of so-called automatic computer systems, criticizing the drawbacks and delays inherent in installing and operating large-scale digital computers and the fact that they are mostly designed for office control, together with the need for data processing being 'designed into the mill' to increase flexibility of the business.

Solving operating problems with electronic computers W. O. Blattner (*AISI Reg. Techn. Meetings*, 1959, 271–284) The use of electronic computers for other than accounting purposes, such as the mathematical treatment and solution of operating and production problems, is described and the benefits associated with them are discussed with the use of codes and programmes and the selection of suitable operating personnel. Examples of types of problems and appropriate methods of solving them are given.

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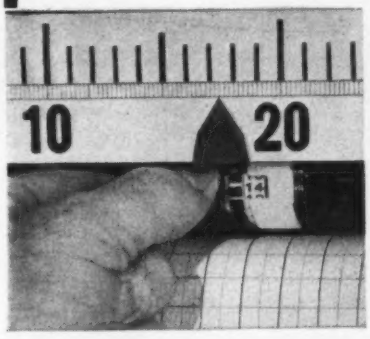

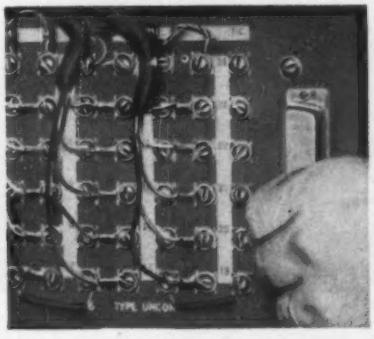

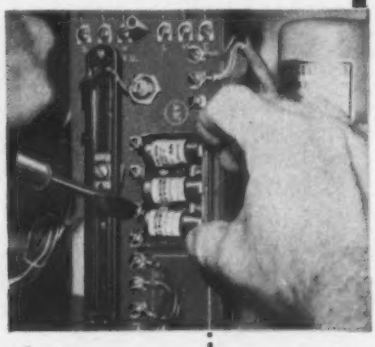

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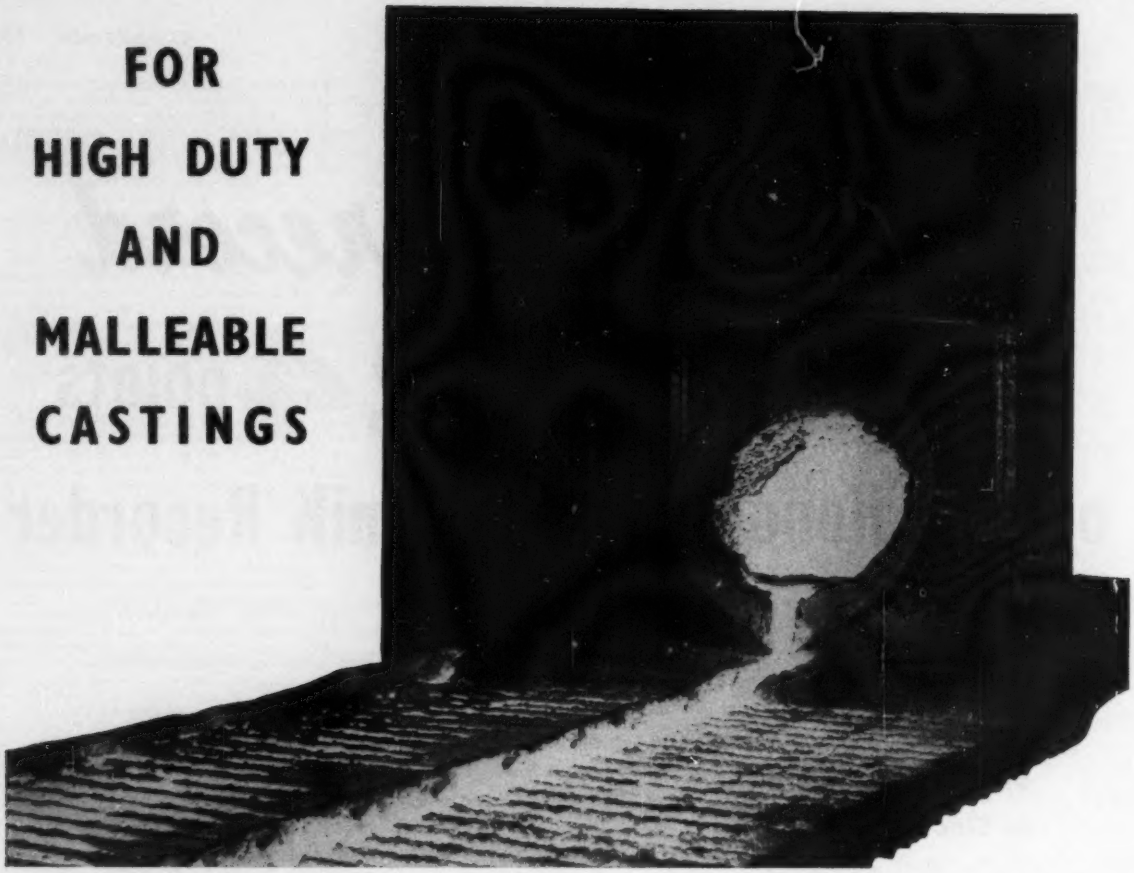

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PHOSPHORUS%	0·6–0·7	0·6–0·7	0·6–0·7	0·4–0·5	0·25	0·25	0·25
MANGANESE%	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5
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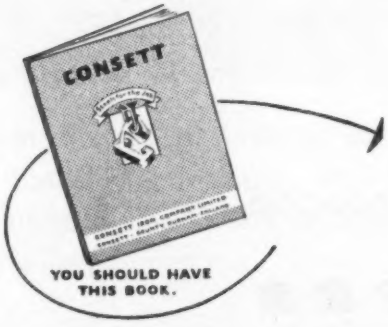

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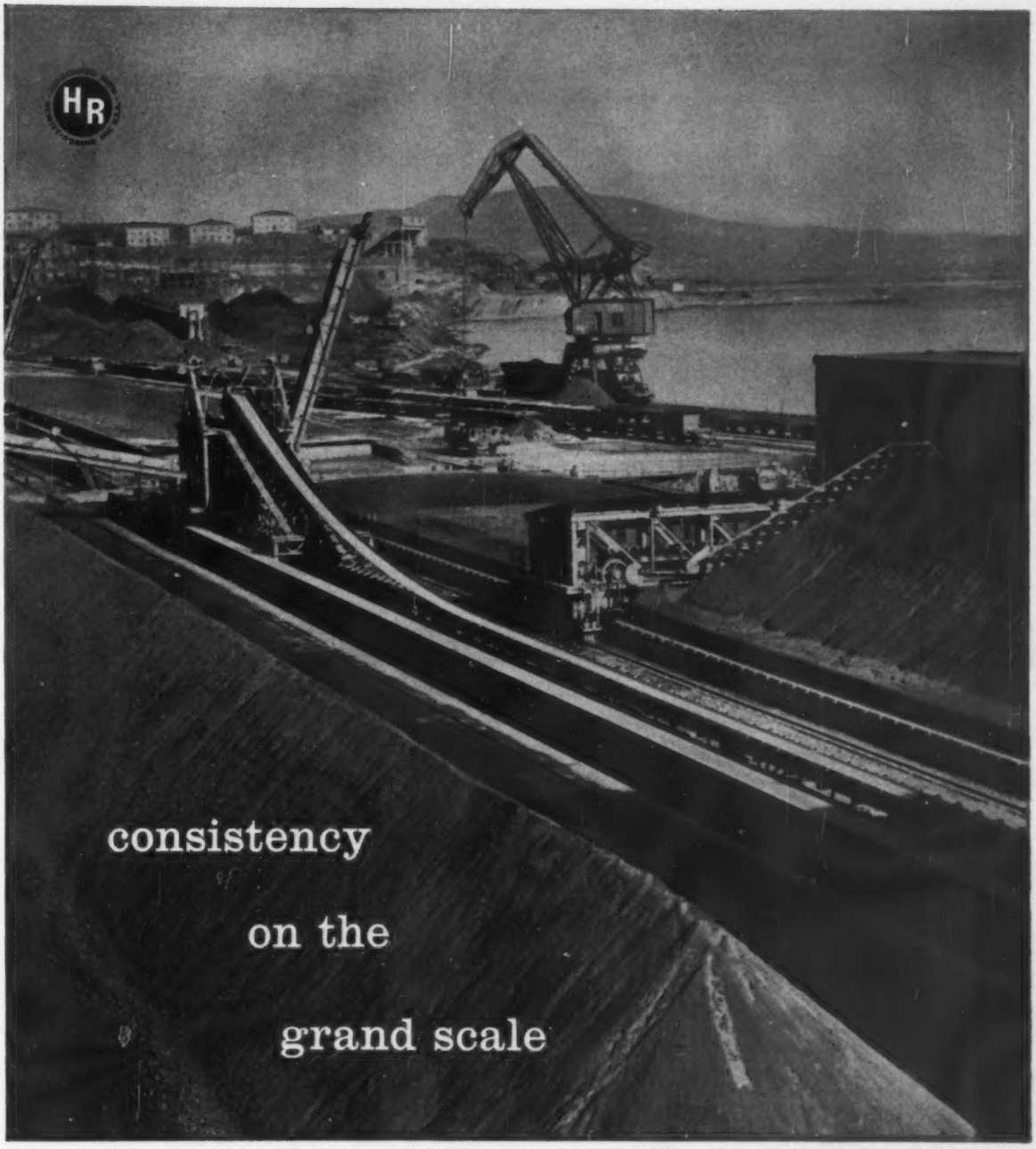

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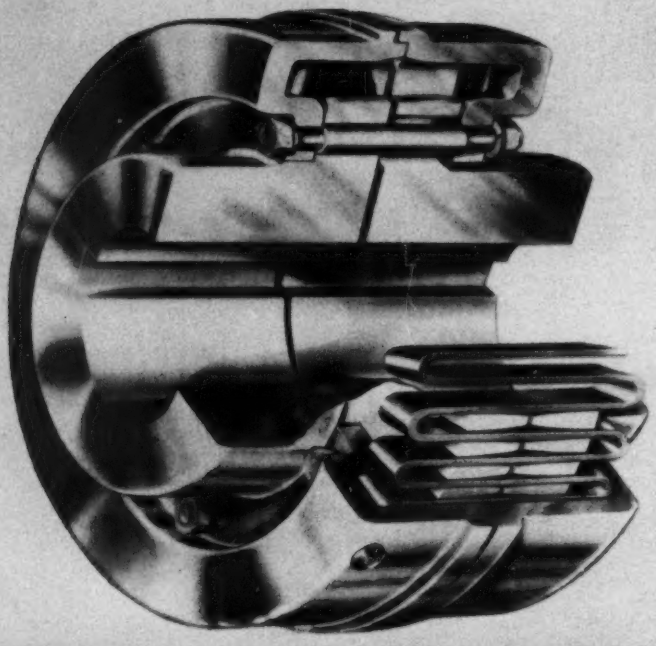

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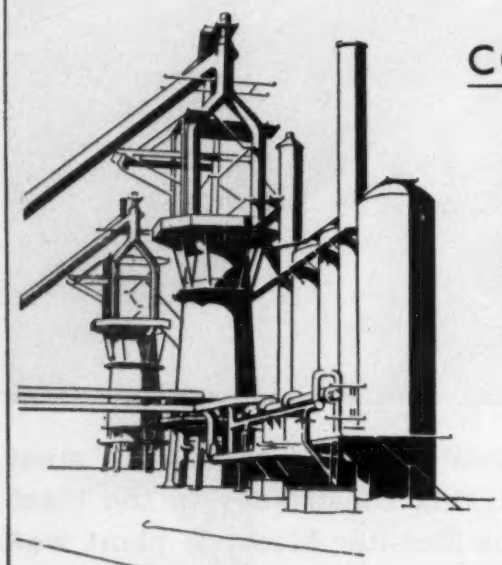

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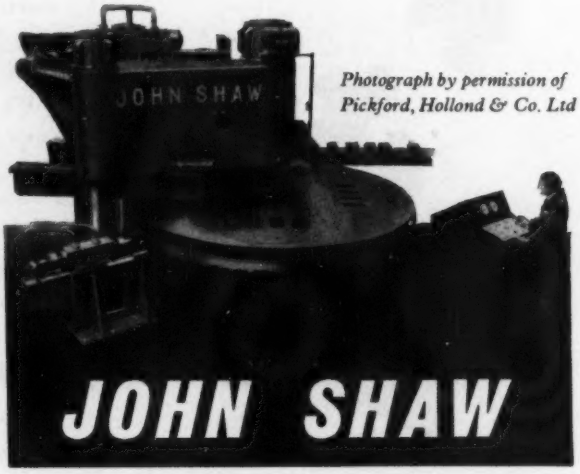

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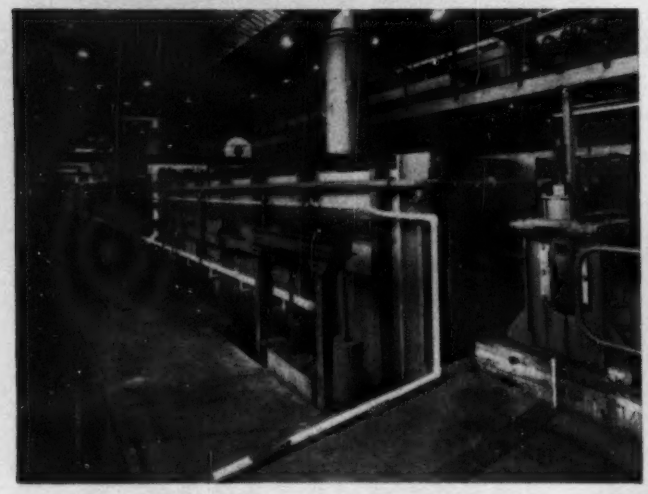

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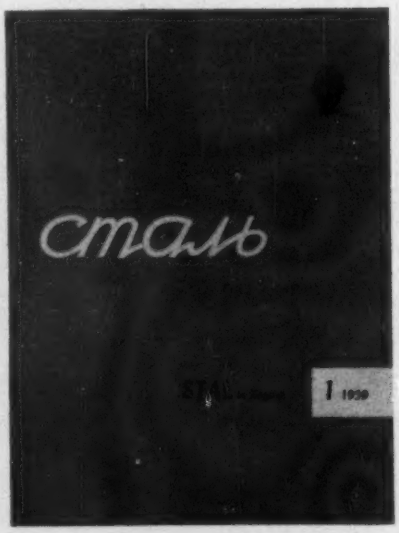

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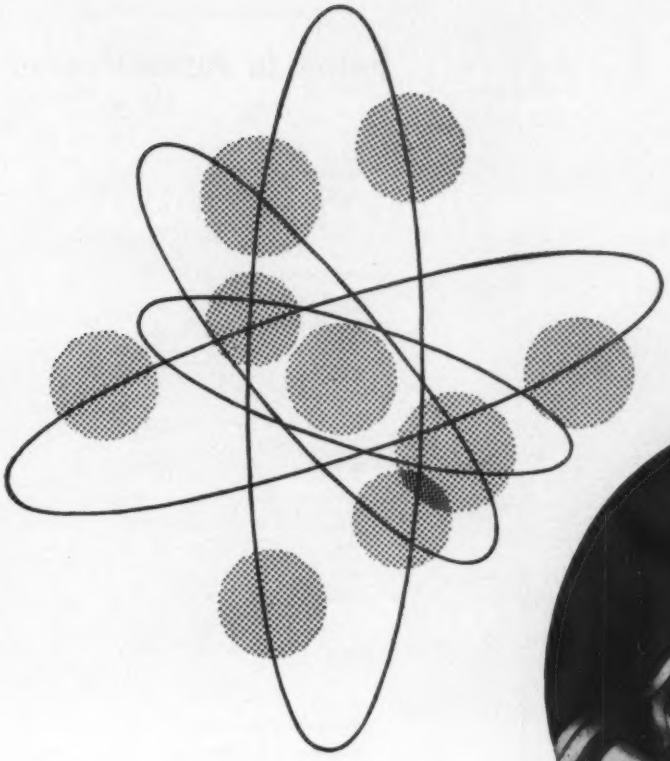

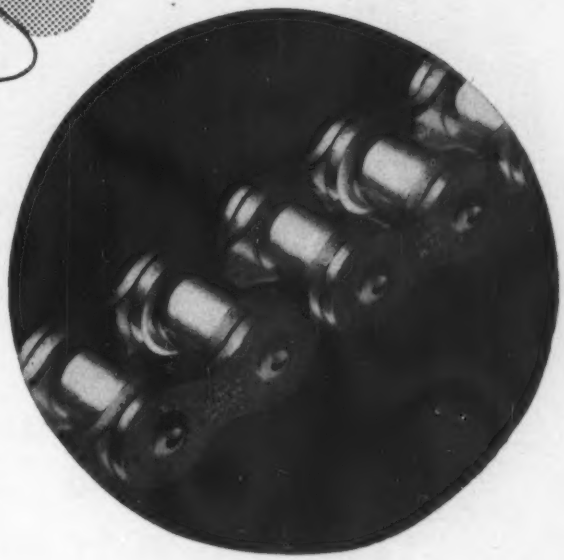

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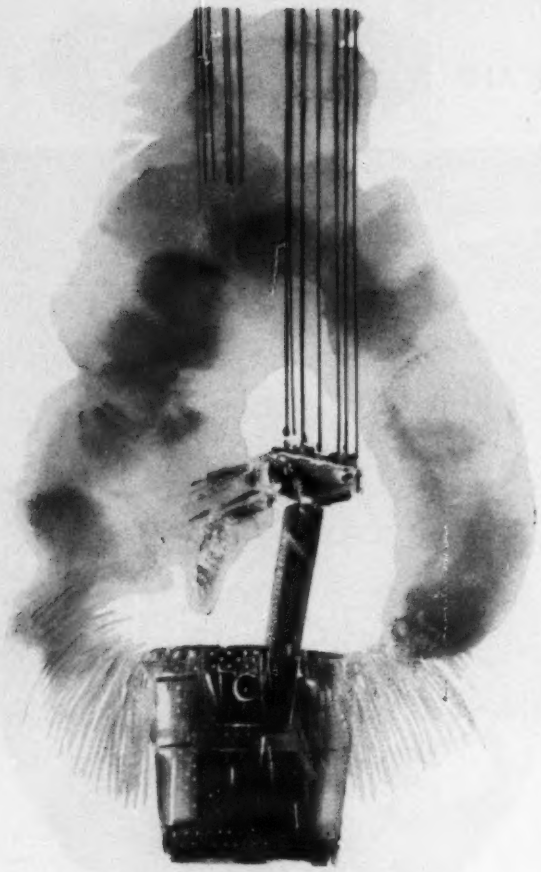

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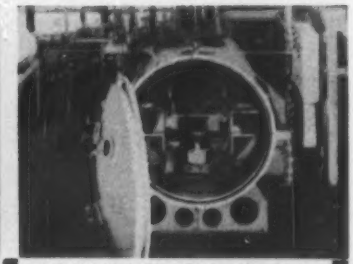

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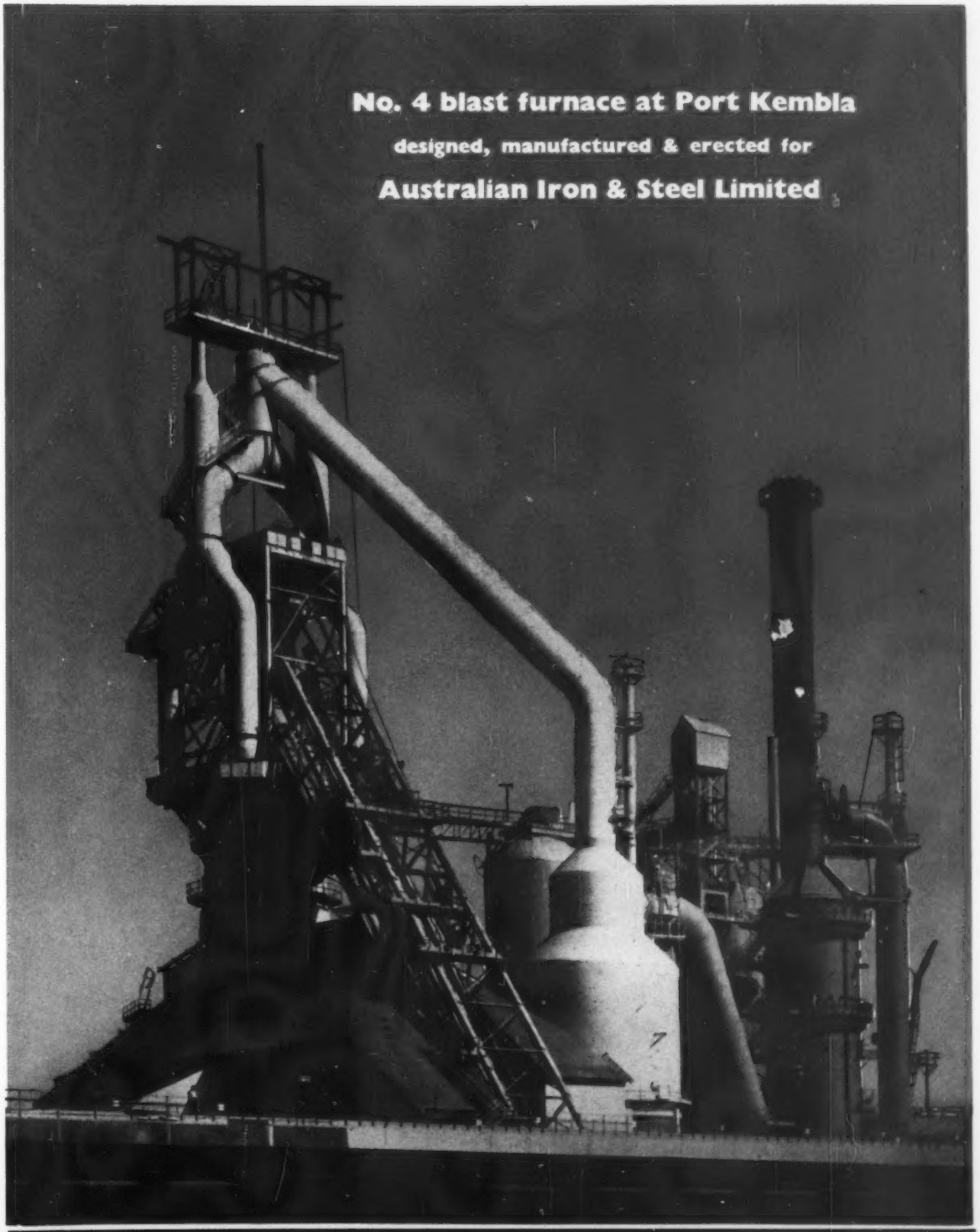

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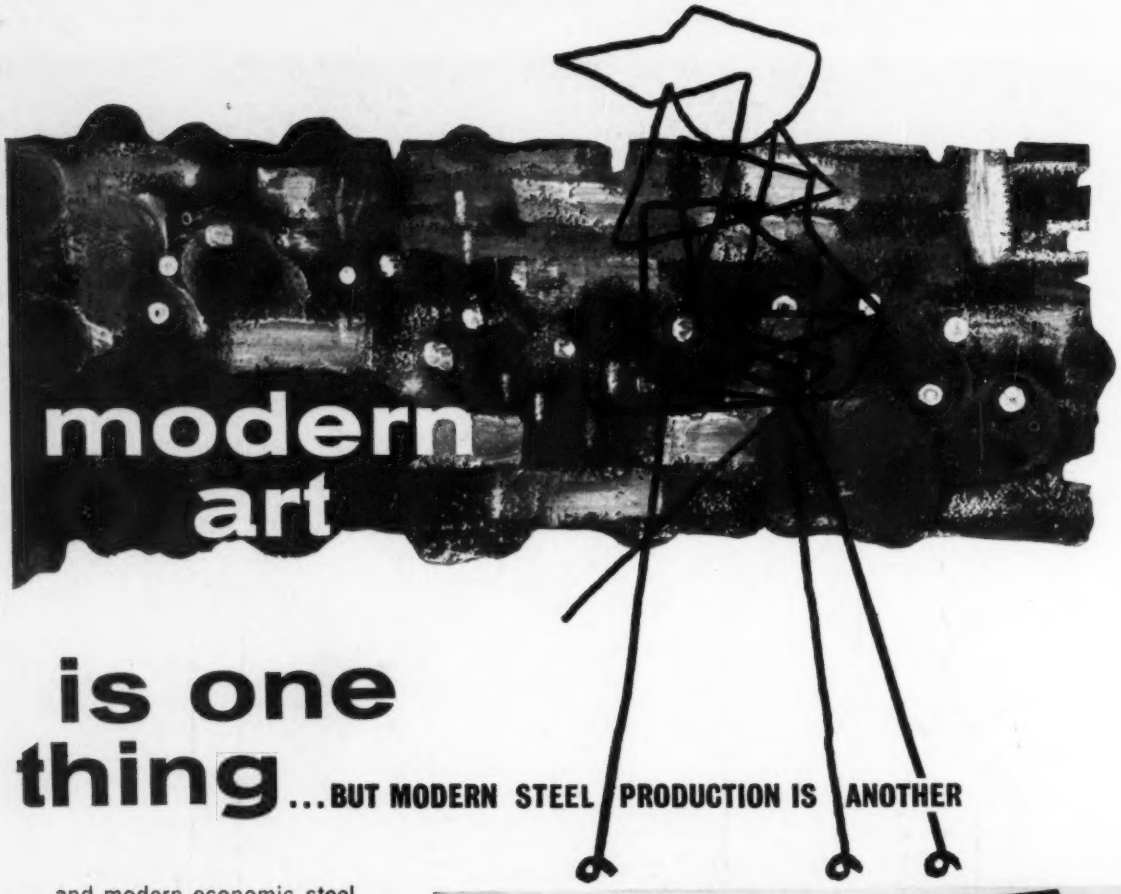

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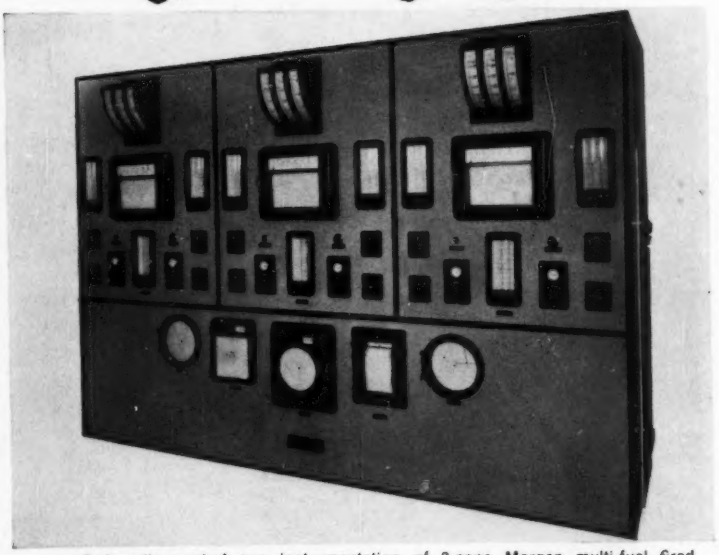

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